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ABSTRACT

This physics laboratory manual is the result of curriculum development begun at Aviation High School (New York City) in 1967. It represents a semester of advanced laboratory work for those students who have completed the usual course in physics. The 91 laboratory experiments included in the manual have been developed and modified through use for three consecutive spring semesters with high school seniors. They have been designed to require the student to do research in the classroom reference library. The laboratory materials needed for the experiments are readily produced by the teacher. It is intended that the students should work independently or in small groups, with many experiments running concurrently. Suggestions are made for implementing this or a similar program in the high school curriculum. (RS)

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CURRICULUM PROJECT REPORT

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APPLIED PHYSICS LABORATORY

An Experimental Program
for
Aerospace Education
12th Year

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Project No. 7510

These experimental materials were prepared as part of the Curriculum Workshop Program of the Bureau of Curriculum Development.

July 1969

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BUREAU OF CURRICULUM DEVELOPMENT
BOARD OF EDUCATION • CITY OF NEW YORK
131 Livingston St., Brooklyn, New York 11201

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APPLIED PHYSICS LABORATORY

An Experimental Program

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Aerospace Education

12th Year

To: Principals of Academic, Vocational and Technical High Schools
From: Dr. David A. Abramson, Acting Director

This experimental curriculum bulletin, Applied Physics Laboratory, has been developed and tried out during the past several years. It is a course utilizing 91 experiments which may be approached on the basis of individualized instruction using laboratory experimental pupil material and equipment designed and built in the school.

This program is designed primarily for twelfth year students who have completed adequate programs in mathematics and science.

We urge the principals of all high schools to consider this program for the current school year. Your comments, suggestions and evaluations are welcome. Would you send these to this office by May 1, 1970.

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PART - I

APPLIED PHYSICS LABORATORY

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John Nick, teacher of science, at Aviation High School was the principal writer of these materials. Mr. Nick developed the program and, with the encouragement and cooperation of the staff, made various modifications during the experimental period. Dr. Daniel A. Salmon, Acting Assistant Director, Bureau of Curriculum Development served as coordinator of this program.

High schools with advanced science programs are urged to try out these materials. Pupils who have completed the regular physic courses can benefit from the unique organization of this plan which makes use of 91 discrete experiments, each requiring simple laboratory materials readily produced in the school.

INTRODUCTION

PRELIMINARY REMARKS

The Applied Physics Laboratory began in 1967 as a cooperative venture of the Bureau of Curriculum Development and Aviation High School. Since then the curriculum progressed to its present form while simultaneously being offered for three consecutive spring semesters to high school seniors who, with few exceptions, have completed the usual year of high school physics and have aspirations for higher education.

As presently conceived, the course is built upon a nucleus of ninety-one experiments. By design, each experiment includes sub-experiments which promote a sense of accomplishment and satisfaction without the necessity for completing the entire experiment. Every effort has been made to have experimentation develop smoothly and efficiently without creating the bogus impression that laboratory work always proceeds with assembly line monotony toward the successful conclusion. The student typically leaves the laboratory feeling that he has mastered some, but not all, of the problem and in the process acquires that healthy sense of frustration which acts as a spur for subsequent effort.

A large reference library located directly in the laboratory

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A large reference library located directly in the laboratory plays a central role in APL curriculum philosophy. Practically all of the experiments require student research in the readily available reference materials before experimentation can proceed successfully.

Apparatus is usually set up according to specifications but enough novelty remains to challenge student ability and imagination. A cursory examination of the annotated list of experiments reveals ample opportunity for team and individual initiative. Data recorded in appropriate tables is examined for significant structure and graphed to reveal the mathematical order behind the phenomena. During each experiment, a preliminary report including sketches, procedures, tables, calculations, graphs, references, and conclusions is prepared. The adequacy of the preliminary report is determined by the extent to which it facilitates the completion of a finished report.

AN ANNOTATED LIST OF EXPERIMENTS

Exp. #1 Review physics via film strips. Especially effective for teams requiring a refresher in some aspect of physics.

Exp. #2 An examination of the literature. Typically the first step in any research.

Exp. #3 An opportunity to peer beyond the classroom and make distant measurements using parallax and a split rangefinder.

Exp. #4 Involves indirect measurements emphasizing the measurement of many objects to reduce the error in approximating the dimensions of one. Determining the volume of a drop of water and measuring the thickness of a sheet of paper with a meter stick arouse a new interest in measurement.

Exp. #5 Approximate areas using graph paper, formulas, and the proportionality of mass and area. Draws attention to the calculus.

Exp. #6 Approximate volumes using displacement, formulas, and the proportionality of mass and volume.

Exp. #7 Determine the densities of regular and irregular objects using mass measurements, and volume formulas and displacements. Critically compare techniques. Identify liquids via density.

Exp. #8 Determine the densities of liquids and the densities of irregular objects lighter than water. Identify liquids via density. Determine density of liquid sealed in black box container.

Exp. #9 Make direct and indirect time measurements. Use easily timed rotation of a phonograph to measure a free fall involving a small fraction of a second.

Exp. #10 Make a simple but workable vernier and then justify the theory involved.

Exp. #11 Line up plate edge parallel to a surface plate using a dial indicator. Locate hole centers using plug gauges, vernier height gauge, dial indicator, angle plate and surface plate. Students devise method for checking slot width and location.

Exp. #12 Measure molecule length using parabolic light shadow and graph paper (Exp. #5) to estimate oil film area, and many drops of a solution to estimate oil volume (Exp. #4).

Exp. #13 Experimentally develop equation for ellipse area using tilted circle, parabolic light, and graphically determined constant of proportionality.

Exp. #14 Experimentally examine factors in pendulum period.

Exp. #15 Consider Foucault pendulum as evidence of earth's rotation. Critically examine Galileo's evidence for rotation of earth.

Exp. #16 Develop a simple table of logarithms using arithmetic. Construct and test slide rule 1 meter long.

Exp. #17 An introduction to or review of slide rule operations: multiplication, division, squaring, square root extraction, cube root extraction, logarithms and higher roots, simple trig functions, and applica-

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Exp. #17 An introduction to or review of slide rule operations: multiplication, division, squaring, square root extraction, cube root extraction, logarithms and higher roots, simple trig functions, and application of the laws of sines and cosines. After this experiment, students find it expeditious to use slide rule for computations.

Exp. #18 Use the inclined plane and extrapolation to determine g, the acceleration of freefall.

Exp. #19 A first attempt at completing a written report using the preliminary data gathered and recorded during a prior experiment. Stresses individual effort and achievement.

Exp. #20 Apply extrapolation to the determination of absolute zero.

Exp. #21 Direct measure free fall time using an electromagnet, spring switch, and 0.01 sec. clock. Calculate g, the acceleration of gravity and verify that it is a constant near the surface of the earth.

Exp. #22 Experimentally examine pendulum motion using a calibrated timer and tape. Consider instantaneous acceleration via $\overline{v}$ vs t and $\overline{a}$ vs t graphs.

Exp. #23 Investigate Newton's 2nd law using Atwood's machine. Compensate for friction.

Exp. #24 Re-examine Newton's 2nd law with cart accelerated along level course. Use graph to determine magnitude of frictional forces involved.

Exp. #25 Probe Hooke's Law and spring stiffness constants. Measure loaded beam deflection to 0.001" using electric circuit and bulb to eliminate unwanted loading by micrometer screw. Devise experiment for determining rubber band's elasticity.

Exp. #26 Experiment with force vectors and verify that "when a particle is acted upon by three forces, the necessary and sufficient condition for equilibrium is that the three forces lie in one plane and that each force be proportional to the sine of the angle between the other two."

Exp. #27 An attempt to experimentally develop $F = \frac{mv^2}{r}$

Exp. #28 A re-examination of $F = \frac{mv^2}{r}$ with a vector application.

Exp. #29 The last of two finished written reports required for the term. Essentially an individual effort.

Exp. #30 Tape timer applied to measuring the velocities, momentums, and kinetic energies of carts separated by a spring "explosion."

Exp. #31 Devise experiment for measuring the acceleration of gravity utilizing a pendulum and/or Atwood's machine.

Exp. #32 Investigate a purportedly general rule used to determine pulley IMA. Includes an encounter with "the fool's tackle." Consider absence of pulleys in human body.

Exp. #33 Measure coefficients of friction using inclined plane and constant speed.

Exp. #34 Measure coefficients of friction by a method which avoids the necessity for moving objects being tested at constant speed. Students are challenged to derive (with hints) the ingenious equation employed.

Exp. #35 Determine the mechanical advantages of pulley systems, worm and worm wheel, gear train, differential chain hoist, and screw jack. Ascertain the efficiency of each machine using ideal and actual mechanical advantages and also effort magnitude.

Exp. #36 Relate water head and pressure. Measure atmospheric pressure with a bicycle pump. Use bicycle pump to relate air volume and air pressure.

Exp. #37 Relate air volume and absolute pressure using an unbalanced mercury column and mercury under pressure. Critically evaluate the equipment and techniques used.

Exp. #38 The students' favorite. Hit falling target with nylon ball fired from an air cannon and explain why the projectile will invariably hit the falling target, despite

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Exp. #38 The students' favorite. Hit falling target with nylon ball fired from an air cannon and explain why the projectile will invariably hit the falling target, despite variations in muzzle velocity, if the projectile is aimed directly at the target before it falls and if muzzle velocity is sufficient for the projectile to reach the falling target.

Measure muzzle velocity using level gun, range, and h (depth projectile falls to reach ground.) Compare calculate air pressure with gauge air pressure.

Exp. #39 Record actual trajectories of sphere leaving launching pad. Includes test of physical intuition relating trajectory to that on another planet. Students asked to prove projectile path is parabolic.

Exp. #40 Examine trajectory of ejected water. Measure water velocity using water range and water volume, and compare results with Torricelli's Theorem. Consider 'vena contracta' consequences.

Exp. #41 Utilize constructed manometer to measure gas pressure at laboratory jet. Measure pressure variations within venturi tube as air speed varies.

Exp. #42 Measure wind tunnel air speed with pitot tube and manometer. Increase measurement sensitivity using tilted tube.

Derive $v = \sqrt{\frac{2ghd'}{d}}$ from Bernoulli's equation, where
d' = liquid density
d = air density
h = water height differential

Exp. #43 Moments applied to calibrating a torque wrench. Apply double weighing and derive $W_x = \sqrt{W_1 W_2}$

Exp. #44 Apply moments to locating airplane C.G. Verify Archimedes: "The magnitudes whether commensurable or incommensurable balance at distances reciprocally proportional to the magnitudes."

Exp. #45 Contrast the mathematical and physical methods of locating centers of gravity. Demonstrate that "If a triangle is divided into 2 parts by a line drawn through the vertex and the center of gravity, the two triangles so formed have equal areas and the line connecting their centroids is parallel to the side opposite (the vertex) and is one third the length of that side."

Exp. #46 Weigh the team's signatures using an analytic balance, the method of vibrations, and balance sensitivity.

Exp. #47 Experimentally examine the velocity, energy, momentum, and impulse factors in 'pile driving.'

Exp. #48 Experimentally investigate the factors in spring vibration. Theoretically and experimentally develop $T = 2\pi\sqrt{\frac{m}{k}}$

Devise method for measuring mass in outer space.

Exp. #49 Graphically derive the inverse square law of gravitation for a satellite pursuing an elliptical orbit and obeying Newton's and Kepler's 2nd laws.

Exp. #50 Locate satellites in space using a simple rangefinder. Determine the diameters of distant satellites and calculate the position vectors between satellites located in space.

Exp. #51 Using a wind tunnel and a lift and drag balance, measure the drag offered by various shapes.

Exp. #52 Experimentally relate lift, angle of attack, and relative wind speed. Measure absolute pressures on an airfoil.

Exp. #53 Measure resistances with an ohmmeter. Interpret resistor color code and categorize resistors according to tolerances. Calibrate ohmmeter for accurate measurements using adjustments and standard resistances.

Exp. #54 Hook up series, parallel, and series-parallel circuits. Measure and calculate total resistances using $R_T = \frac{R}{N}i$; $R_T = \frac{R'R''}{R'+R''}$; and $\frac{1}{R_T} = \frac{1}{R'} + \frac{1}{R''} + \cdots + \frac{1}{R^n}$

Exp. #41 Utilize constructed manometer to measure gas pressure at laboratory jet. Measure pressure variations within venturi tube as air speed varies.

Exp. #42 Measure wind tunnel air speed with pitot tube and manometer. Increase measurement sensitivity using tilted tube.

Derive $v = \sqrt{\frac{2ghd'}{d}}$ from Bernoulli's equation, where

d' = liquid density
d = air density
h = water height differential

Exp. #43 Moments applied to calibrating a torque wrench. Apply double weighing and derive $W_x = \sqrt{W_1 W_2}$

Exp. #44 Apply moments to locating airplane C.G. Verify Archimedes: "The magnitudes whether commensurable or incommensurable balance at distances reciprocally proportional to the magnitudes."

Exp. #45 Contrast the mathematical and physical methods of locating centers of gravity. Demonstrate that "If a triangle is divided into 2 parts by a line drawn through the vertex and the center of gravity, the two triangles so formed have equal areas and the line connecting their centroids is parallel to the side opposite (the vertex) and is one third the length of that side."

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Exp. #55 Experimentally examine the relationship between voltage and current in a simple circuit.

Exp. #56 Measure resistance using the voltmeter-ammeter method. Study the effect of voltmeter current on ammeter reading and vice versa.

Exp. #57 Investigate variations of wire resistance with changes in wire length, diameter, and material.

Exp. #58 Probe variations of wire resistance with changes in temperature. Examine fuse vs temperature action.

Exp. #59 Measure the distribution of current in series, parallel, and series-parallel circuits. Investigate current behavior at circuit nodes.

Exp. #60 Measure the distribution of voltage in series, parallel, and series-parallel circuits. Investigate voltage behavior in circuit loops.

Exp. #61 Associate circuit shorts and opens with symptoms using electrical laws and voltmeter readings. Students make judgment based on theory and then check judgment against actual circuit which includes the short or break.

Exp. #62 The teacher's favorite. A qualitative analog of Exp. #61. Affords 50 trouble shooting opportunities. Team members compete against one another by making theoretical judgments regarding circuit symptoms and circuit difficulties and then actually wiring the circuit including the difficulty. Erroneous judgments require explanation before proceeding to the next more difficult circuit. A simple, inexpensive experiment which is easily rated by the competing team members.

Exp. #63 Construct a Wheatstone bridge and measure resistances with it. Derive bridge equation, consider bridge accuracy when $L_m \doteq L_x$, and examine the possibility of improving measurements with dual readings including those made with battery polarity reversed.

Exp. #64 Design, construct, and calibrate a voltmeter. An introduction to a simple voltage divider, multipliers, constant current generator and the half current method of measuring the small resistance of a galvanometer movement.

Exp. #65 Design, construct, and check switching circuits. Circuits graded according to difficulty--no hints.

Exp. #66 Design, construct, and check ohmmeter.

Exp. #67 Apply Kirchhoff's Laws and simultaneous equations to electrical networks.

Exp. #68 Measure resistances wired in 3 dimensional configurations. Apply π and T transformations in circuit analysis.

Exp. #69 Simplified approach to complicated resistance configurations using Kirchhoff's Laws.

Exp. #70 Measure electrical power and work and the conversion of electrical energy into heat. Experimentally determine Joule's mechanical equivalent.

Exp. #71 Experimentally determine the temperature coefficients of electrical resistance for copper and nichrome, and apply them to indirectly measuring the temperatures of an operating motor, an operating transformer, and an operating hot plate.

Exp. #72 Measure the power transfer of a black box power supply under varying load. Use semilogarithmic graph paper to determine the condition for maximum power transfer. Consider possibility of generalizing the findings.

Exp. #73 Measure the equivalent voltages and resistances of three black box circuits and then verify that these "unknown" complex circuits

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Exp. #73 Measure the equivalent voltages and resistances of three black box circuits and then verify that these "unknown" complex circuits can actually be replaced by simple Thevenin equivalent circuits. After practical verification, expose black box circuits, examine contents and attempt to rationalize and generalize experimental findings.

Exp. #74 Design, construct, and test L-Pads. Examine variable L-Pad and determine the mathematical structure of the variable resistances.

Exp. #75 Experimentally investigate and apply Lenz's Law to self induction, mutual induction and transformer action.

Exp. #76 Measure magnetic attraction and repulsion and relate to the inverse square law.

Exp. #77 Measure AC voltage and frequency with an oscilloscope. Measure tuning fork frequency with a microphone and an oscilloscope.

Exp. #78 Determine the charges carried by copper and hydrogen ions in solution. Measure coulombs and moles.

Exp. #79 Use the earth's magnetic field to determine the factors in magnetic field strength.

Exp. #80 Use current balance to measure coil magnetic induction in $\frac{\text{newtons}}{\text{ampere-meter}}$ and gausses.

Exp. #81 Use electron curvature in a 6AF6 tube and in a known magnetic field to determine the mass of an electron.

Exp. #82 Experimentally analyze the operation of a synchro system. Apply vectors to synchros.

Exp. #83 Examine capacitor charging and its relation to the RC constant of the circuit. Compare experimental results with the theoretical universal curve.

Exp. #84 Measure starting and stopping voltages of a neon bulb. Design and construct relaxation oscillators. Associate saw tooth curve with TV picture production and radar range finding.

Exp. #85 Investigate AC voltage distribution in series circuits containing resistors and capacitors. Apply vectors to AC circuit voltage.

Exp. #86 Theoretically develop $X_c = \frac{1}{2\pi fC}$ and experimentally compare with $X_c = \frac{V}{I}$

Graphically verify that $I_{av} = 0.637\ I_{max}$ using a) graph paper squares
b) sine table values
c) "mass" of sine curve

Study capacitor's non-resistive opposition to electron flow.

Exp. #87 Observe effect of laminated iron core on a coil's non-resistive opposition to electron flow. Determine the effect of frequency on a coil's inductive reactance. Calculate coil inductance in henries. Experimentally compare $X_L = Z = \frac{V}{I}$ and $X_L = 2\pi fL$. Explain why coil resistance plays an increasingly minor role in coil impedance as frequency increases.

Exp. #88 Experimentally examine series circuit resonance. For a given coil, graph resonant frequency vs. capacitance. Explain curve's form and how it will be affected by increased resistance. Determine coil inductance via $L = \frac{1}{4\pi^2 f^2 C}$.

Exp. #89 Experimentally examine parallel circuit resonance. Measure impedance of tank circuit using voltmeter. Calculate coil inductance assuming that $X_L = X_c$ for a resonant circuit. Observe and explain the damped harmonic oscillations of a resonant tank circuit. Design tank

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Exp. #90 Measure frequencies using Lissajous patterns on an oscilloscope. Theoretically develop Lissajous figures and generalize both theoretical and experimental findings.

Exp. #91 Experimentally discover unidirectional flow in an ammonium phosphate solution with lead and aluminum strips. Examine operation of 1B3 tube (use tube manual for hook-up) with negative and positive plates. Wire and trace the electron flow of a half-wave semiconductor rectifier. Wire and trace the electron flow of a full-wave semiconductor rectifier. Examine the wave forms with an oscilloscope. Wire a square wave generator and explain its operation.

COURSE ORGANIZATION AND EQUIPMENT

Except for the first three days of experimentation only one set of equipment is required for each experiment thereby keeping cost and storage requirements at a minimum. By the fifth day classes are grouped into ten teams with each team engaged in a different experiment. Thereafter, a new experiment is introduced daily while a completed one is withdrawn. The modest 10% reorganization of the laboratory per day not only makes the completion of 91 different experiments feasible but also enhances course flexibility since the cost of a single set up usually will neither deter the introduction of a new experiment nor impede the rejection of an inappropriate one.

Laboratory work begins immediately following the first day of the term during which students are enrolled, grouped into teams with a minimum of 3/team, and general information is imparted to the students. The teams, usually ten in number, are identified by letters A through J, move into sequential order as follows:

Day	2	3	4	5
Team	G	I	J	A
Exp #	2	2	2	11

Station #6

Day	2	3	4	5
Team	H	H	I	J
Exp #	2	2	2	2

Station #7

Day	2	3	4	5
Team	E	G	H	I
Exp #	3	3	3	3

Station #8

Day	2	3	4	5
Team	D	F	G	H
Exp #	4	4	4	4

Station #9

Day	2	3	4	5
Team	A	D	F	G
Exp #	5	5	5	5

Station #10

AVIATION HIGH SCHOOL -- APPLIED PHYSICS LABORATORY

Day	2	3	4	5
Team	F	B	D	F
Exp #	3	6	6	6

Station #1

Day	2	3	4	5
Team	I	A	C	E
Exp #	1	7	7	7

Station #2

Day	2	3	4	5
Team	J	J	B	D
Exp #	1	1	8	8

Station #3

Day	2	3	4	5
Team	C	E	A	C
Exp #	4	4	9	9

Station #4

Day	2	3	4	5
Team	B	C	E	B
Exp #	5	5	5	10

Station #5

The first five experiments require some duplication but create no equipment difficulties. The fifth day of the term finds lead Team A at station #6 doing Exp. #11, team B at station #5 doing Exp. #10, team C at station #4, etc. etc. If team J exists it spends two days doing Exp. #1 and two days doing Exp. #2--an excellent opportunity to review physics while enabling the teams to fall in line. Team I devotes two days to Exp. #2. No other experiment duplications occur for the rest of the term.

Because the Applied Physics Laboratory was subjected to trial while being written, the expected gap between impossible dreams and practice narrowed. Experiments were necessarily selected to fit materials accessible to Aviation High School. Simplicity rules the laboratory engaged in a different experiment. Thereafter, a new experiment is introduced daily while a completed one is withdrawn. The modest 10% reorganization of the laboratory per day not only makes the completion of 91 different experiments feasible but also enhances course flexibility since the cost of a single set up usually will neither deter the introduction of a new experiment nor impede the rejection of an inappropriate one.

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Team	G	I	J	A	H	H	I	J	E	G	H	I	D	F	G	H	A	D	F	G
Exp #	2	2	2	11	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
	Station #6				Station #7				Station #8				Station #9				Station #10			

AVIATION HIGH SCHOOL -- APPLIED PHYSICS LABORATORY

Day	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
Team	F	B	D	F	I	A	C	E	J	J	B	D	C	E	A	C	B	C	E	B
Exp #	3	6	6	6	1	7	7	7	1	1	8	8	4	4	9	9	5	5	5	10
	Station #1				Station #2				Station #3				Station #4				Station #5			

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Because the Applied Physics Laboratory was subjected to trial while being written, the expected gap between impossible dreams and practice narrowed. Experiments were necessarily selected to fit materials accessible to Aviation High School. Simplicity rules the laboratory set ups and in the electricity experiments a positive effort avoided the inclusion of console apparatus where the price for adaptability is a dull obscurity in which the important ideas are lost and the student is deprived of contact with the component parts.

Abortive attempts to classify apparatus verbally with the repeated use of "fixture", "holder", etc. soon became mired in hopeless ambiquity. Now, photographs afford an instant inventory of materials required for individual experiments. Three years of experience prove that photographs effectively relieve the teacher from the onerous task of assuring the availability of the thousands of items needed to keep 91 different experiments working. With minimal effort students capably assume responsibility for apparatus.

REFERENCE LIBRARY

By design, the experiments require frequent research in the literature. For convenience a library consisting of more than 300 volumes is located directly in the laboratory. Although specific references on the experiment sheets suggest a direction research may profitably take, the student is urged to, and with experience does, develop his own proficient method of investigation. Indeed, this may well be the most important outcome of the laboratory-research approach to learning. The arbitrary list of references must of course change as the library grows. Through reading contact with leading minds in the world of science, students are encouraged to expand their horizons beyond the confines of the classroom and to rise above limitations they may have unnecessarily placed upon themselves. The ability to research a problem will be a valuable asset in whatever field the student eventually pursues.

A partial list of present holdings follows:

Adams, Thomas. Transistor Circuits. 2nd ed. Indianapolis: Howard W. Sams & Co., 1966.

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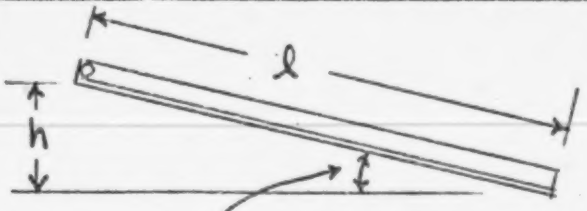
RECORDING EXPERIMENTAL DATA & MAKING PRELIMINARY ANALYSIS OF DATA

1. Complete heading on top of report: (Provide 3/4" margin on left)
    - a) Experiment title.
    - b) Date
    - c) Names in alphabetical order--including official class.
    - d) Attendance:
        - ⧄ → on time at beginning of lab session.
        - ☒ → present for entire lab session.
        - 15⧄ → reported 15 minutes late to lab.
        - ⧄20 → excused for 20 minutes at end of lab session.
2. Describe set-ups and procedures via labeled sketches.
3. Record data with appropriate units in tables.
4. Make necessary calculations - show all work on data sheet.
5. Make large labeled graphs
    --tape graphs into report as shown.
6. Draw preliminary conclusions -- recheck data if necessary.
7. Cite references actually used during experiment.
8. Number pages.

Note: The adequacy of the preliminary report is determined by the extent to which it facilitates the completion of a finished report. Assume that the laboratory will not be available after the preliminary report is completed.

SAMPLE PUPIL WORK SHEET

An Experimental Examination of the Acceleration of Gravity	8-1	Archetti, Louis	20⧄	A
	8-2	Chiro, Jim	☒	
	8-1	Milani, John	☒	18
Feb. 17, 1968 Page 1	8-2	Rodriguez, Raul	⧄30	



1) set up $\measuredangle$ using trig.

$$\sin\measuredangle = \frac{h}{l} \rightarrow h = l\sin\measuredangle$$
$$= 4(.02618)$$
$$= 0.104\text{ m}$$

2) Using stop watch, measured time for ball to roll down incline.
- let t equal average of 3 trials

3) Calculated a:

$$s = v_i t + \frac{at^2}{2} \rightarrow a = \frac{2s}{t^2} = \frac{2(4)}{(5.6)^2} = .255 \text{ m/sec}^2$$

Ref: Halliday & Resnick Physics pg. 41

$\measuredangle$	h (m)	l (m)	h/l	t (sec.)	a (m/sec²)
1.5	0.104	4	0.026	5.6	0.255

b) Date

c) Names in alphabetical order--including official class.

d) Attendance:

⧄ → on time at beginning of lab session.

☒ → present for entire lab session.

⧄ 15 → reported 15 minutes late to lab.

⧄ 20 → excused for 20 minutes at end of lab session.

2. Describe set-ups and procedures via labeled sketches.
3. Record data with appropriate units in tables.
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SAMPLE PUPIL WORK SHEET

An Experimental
Examination of the
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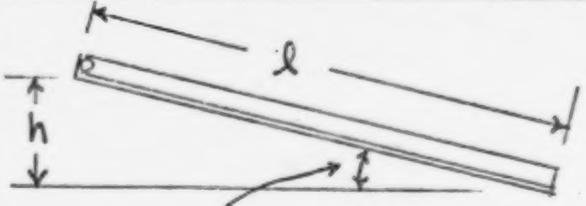
Feb. 17, 1968 Page 1

8-1	Archetti, Louis	20 ⧄	A
8-2	Chiso, Jim	☒	
8-1	Milani, John	☒	18
8-2	Rodriguez, Raul	⧄ 30	



1) set up ∡ using trig.

$\sin \measuredangle = \frac{h}{l} \rightarrow h = l \sin \measuredangle$
$= 4(.02618)$
$= 0.104\ m$

2) Using stop watch, measured time for ball to roll down incline.
- let t equal average of 3 trials

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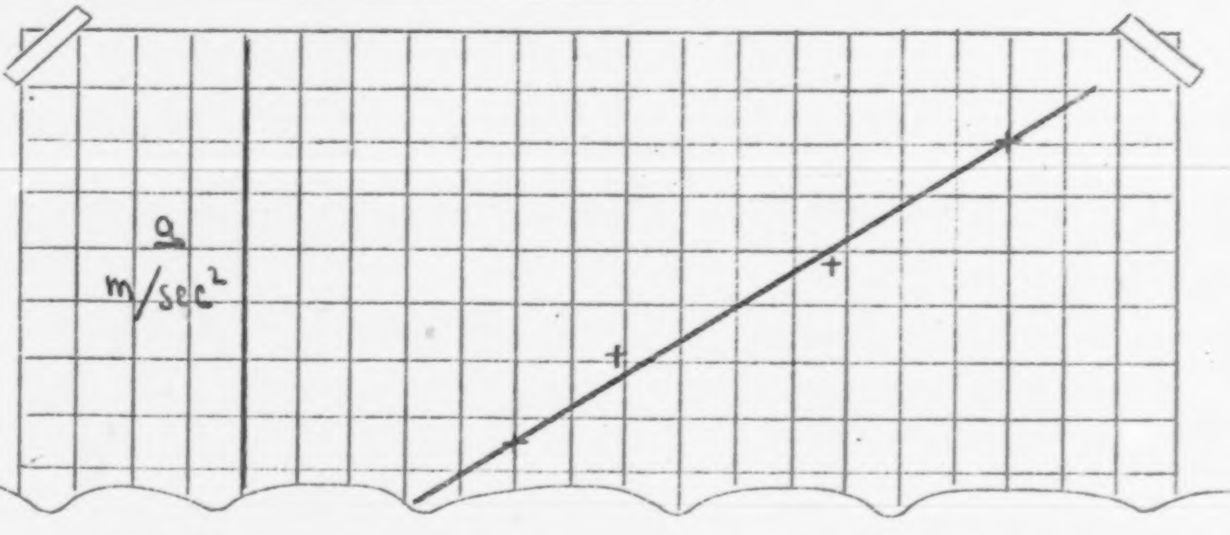
Ref: Halliday & Resnick
Physics pg. 41

∡	h (m)	l (m)	h/l	t (sec.)	a (m/sec²)
1.5	0.104	4	0.026	5.6	0.255



OTHER SCHOOLS AND THE CURRICULUM

The APL curriculum may have to be adapted for other schools. It was neither designed to be directly applicable nor could it be conceived to fit other schools without modification. To be effective the curriculum must meet the needs of students which vary from school to school and of course even within a school. Nevertheless with variation the curriculum should prove relevant to education elsewhere. In spirit it is applicable to all schools.

While the needs of students primarily determine the content and format of a laboratory course, finances, available equipment, physical plant, instructional time allotment, etc., also require consideration. None of these pose insurmountable problems. Probably half of the experiments in the 1969 sequence can be assembled with minor effort and cost. For example: Exp. #1 ... film strips, projector; Exp. #2 ... a library; Exp. #4 ... nails, washers, pages of a book, meter stick; Exp. #5 ... cardboard figures; Exp. #9 ... phonograph, polar coordinate paper, stopwatch; Exp. #14 ... pendulum, clock; Exp. #16 ... strips of paper, meter stick; Exp. #27 ... assortment of spheres, spring balance; Exp. #44 ... model airplane, balance scales; Exp. #45 ... cardboard figures, string; Exp. #53, #54, #67, #68, and #69 ... precision resistors, ohmmeter; Exp. #62 ... miniature lamps and bases, toy train transformer; Exp. #65 ... battery, lamp, switches.

If a school, as a start, were to offer half as many experiments and if necessary use alternate days for formal instruction, research, report writing, etc., a comparable laboratory program could immediately be instituted with little difficulty. A going library can be quickly assembled by borrowing books from teachers, students, school libraries, etc. When APL was offered for the first time, the major portion of electrical instruments was borrowed from neighboring schools and companies--a veritable mother-lode of scientific equipment.

Even after apparatus has been gathered, care must be taken in scheduling experiments. For example, Exp. #38 "Centripetal Force and Acceleration" and Exp. #38 "Projectiles" must both be performed behind a portable overhead plastic curtain and hence must, at the very minimum, be ten experiment days apart. Similarly Aviation's two wind tunnels which are used for four experiments must be properly scheduled. Exp. #40 "Torricelli's Law" had to be located at station #5 alongside the laboratory's sink since it requires a constant water supply and overflow disposal. For Exp. #50 "Locating Satellites in Space" only stations at the ends of the laboratory permitted maximum ranges for satellites suspended from the ceiling.

The selection and order of experiments will always be determined by the unique needs, interests, and facilities of individual schools. At Aviation, content and course organization have undergone major alterations during each presentation of APL. At the very least, this curriculum offers a series of tested experiments which can be introduced to good advantage in other schools. At best the curriculum will encourage others to experiment with the laboratory--research approach to education and then to engage in an exchange of ideas profitable to all. For, as Aristotle so aptly put it centuries ago:

> "Search for truth is in one way
> hard and in another way easy

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> "Search for truth is in one way
> hard and in another way easy, for
> it is evident that no one can
> master it fully nor miss it
> wholly, but each adds a little
> to our knowledge of nature and
> from all the facts assembled
> there arises a certain grandeur."

COLLEGE ENTRANCE AND SUCCESS:

Of the fifty students participating in the 1969 APL program, all have been accepted by institutions of higher learning:

Admitted to 4 Year Colleges

Brooklyn Polytechnic Institute
- (3) Aeronautical Engineering
- (3) Electrical Engineering
- (1) Mechanical Engineering

City College
- (1) Electrical Engineering
- (1) Mechanical Engineering

City University
- (1) SEEK Program

Florida State University
- (1) Engineering

Fordham University
- (1) Pre-Engineering

Hunter College
- (2) Pre-Engineering
- (1) Liberal Arts (History)

Lehman College
- (3) Pre-Engineering
- (1) Liberal Arts

New York University
- (1) Aeronautical Engineering

Prairie View A. & M. (Texas)
- (1) Engineering

Pratt Institute
- (1) Electrical Engineering

Queens College
- (2) Pre-Engineering

Johnson C. Smith College (N.C.)
- (1) Physics

St. John's University
- (1) Pre-Engineering
- (1) Liberal Arts (Political Science)

U. S. Airforce
- (1) Operation Bootstrap

Admitted to 2 Year Colleges

(All expressing the desire to continue beyond the 2 years and most with that option.)

Bronx Community College
- (1) Engineering Science
- (1) Mechanical Technology

Farmingdale A. & T. College
- (4) Engineering Science

Manhattan Community College
- (1) Electrical Technology

New England Aeronautical Institute
- (1) Aeronautical Technology

New York City Community College
- (2) Electrical Technology
- (2) Mechanical Technology
- (1) Chemical Technology
- (1) Pre-Engineering
- (1) Liberal Arts

Queensborough Community College
- (4) Pre-Engineering
- (2) Electrical Technology
- (1) Mechanical Technology

Unfortunately, the time devoted to developing the APL curriculum has prevented an in-depth study of what happens to those students who gain admission to college and to those who enter have been accepted by institutions of higher learning:

Admitted to 4 Year Colleges

Brooklyn Polytechnic Institute
- (3) Aeronautical Engineering
- (3) Electrical Engineering
- (1) Mechanical Engineering

City College
- (1) Electrical Engineering
- (1) Mechanical Engineering

City University
- (1) SEEK Program

Florida State University
- (1) Engineering

Fordham University
- (1) Pre-Engineering

Hunter College
- (2) Pre-Engineering
- (1) Liberal Arts (History)

Lehman College
- (3) Pre-Engineering
- (1) Liberal Arts

New York University
- (1) Aeronautical Engineering

Prairie View A. & M. (Texas)
- (1) Engineering

Pratt Institute
- (1) Electrical Engineering

Queens College
- (2) Pre-Engineering

Johnson C. Smith College (N.C.)
- (1) Physics

St. John's University
- (1) Pre-Engineering
- (1) Liberal Arts (Political Science)

U. S. Airforce
- (1) Operation Bootstrap

Admitted to 2 Year Colleges

(All expressing the desire to continue beyond the 2 years and most with that option.)

Bronx Community College
- (1) Engineering Science
- (1) Mechanical Technology

Farmingdale A. & T. College
- (4) Engineering Science

Manhattan Community College
- (1) Electrical Technology

New England Aeronautical Institute
- (1) Aeronautical Technology

New York City Community College
- (2) Electrical Technology
- (2) Mechanical Technology
- (1) Chemical Technology
- (1) Pre-Engineering
- (1) Liberal Arts

Queensborough Community College
- (4) Pre-Engineering
- (2) Electrical Technology
- (1) Mechanical Technology

Unfortunately, the time devoted to developing the APL curriculum has prevented an in-depth study of what happens to those students who gain admission to college and to those who enter industry. Perhaps too little time has elapsed for a definitive inquiry. Yet, a very favorable report comes back from the City College of New York. Of the ten APL graduates who entered the City College School of Engineering in 1967, one left after one and one-half years for the Armed Forces, but nine have just successfully completed their sophomore year with the following majors:

- (3) Electrical Engineering
- (3) Mechanical Engineering
- (1) Civil Engineering
- (1) Computer Science
- (1) Oceanography

Team Work at the School

Frank Woehr, Principal; Harry Kase, Administrative Assistant; and Sidney Rock, Chairman, Mathematics-Science Department, supported this experiment in laboratory instruction and generously placed the considerable resources of Aviation High School behind the program. Harry Mertz provided laboratory expertise; Edward Pletsch assisted with research; Louis Capriccio designed and constructed many of the special devices; and Marian Nick contributed typing skill. Students Tai Cheung and Wing Tam made the photographs which kept the materials for ninety one experiments in order and made dozens of beautiful candid action shots.

Maxwell J. Mathews continues to be a prime mover of the program even in retirement.

The American Journal of Physics served as a source for some of the experiments and for many of the quotations used as introductions to the experiments.

Organizing a curriculum and committing it to print though necessary first steps, would in this case yield a mere sequence of experiments with explanatory notes. The 160 students who have completed a total of 4,845 team experiments during the past three spring semesters, put theory to the experimental test, patiently uncovered errors, diligently provided instant feed back, and ultimately must be credited with imparting life to the program. It is a pleasure to cite each of the following students for his contributions to the APL curriculum:

APL 1967

M. Abreu
R. Abreu
V. Albit
G. Alcorta
M. Alvarez
C. Atkins, Jr.
I. Bauland
D. Berlingieri
G. Blanchard
E. Campbell
R. Cater
R. Chernick
G. Chin
T. Chin
J. Colon
A. Dames
A. Dickerson
J. Eiche
D. Eng
A. Firestone
S. Gancasz
A. Gee
C. Giordano
G. Grossi
E. Hang
N. Jaremko
S. Jung
P. Lai
S. Lane
C. Lee
L. Ma
M. Martinez
R. Mercurio
J. Montalvo
G. Neumann
R. Nizza
W. Poy
M. Punziano
P. Raanan
T. Rogers
P. Romeo
R. Santiago
E. Schiavone
M. Schulman
A. Seibold
H. Soohoo
G. Terlecki
W. Tow
J. Vasquez
W. Walenta
S. Wan
J. Wu

APL 1968

L. Archetti
W. Ben
L. Bisonni
P. Borkowski
M. Caballero
J. Chin
J. Clark
J. Comunale
M. Czarny
N. Decanditis
M. Delerme
G. DeLisser
R. Durante
A. Eng
W. Grabe
J. Graff
J. Grassi
P. Hadatschi
C. Haden
K. James
C. Kalinoski
B. Keels
D. Krzyzewski
P. Leon
J. Lew
S. Mark
J. Martinez
J. Masefield
T. Masser
A. Masterpalo
M. McCrawford
J. Milani
P. Moy
P. Moy
P. Muller
A. Nachajski
M. Nadler
A. Negron
G. Nizza
H. Opdal
P. Parisi
R. Peterson
M. Powell
R. Quinones
W. Rao
R. Reiss
R. Rodriguez
L. Rojas
T. Rosa
R. Sanchez
G. Sardis
R. Seissian
J. Torres
J. Trabazo
D. Vaudo
R. Villavasso
S. Whing
M. Yu

resources of Aviation High School behind the program. Harry Mertz provided laboratory expertise; Edward Pletsch assisted with research; Louis Capriccio designed and constructed many of the special devices; and Marian Nick contributed typing skill. Students Tai Cheung and Wing Tam made the photographs which kept the materials for ninety one experiments in order and made dozens of beautiful candid action shots.

Maxwell J. Mathews continues to be a prime mover of the program even in retirement.

The American Journal of Physics served as a source for some of the experiments and for many of the quotations used as introductions to the experiments.

Organizing a curriculum and committing it to print though necessary first steps, would in this case yield a mere sequence of experiments with explanatory notes. The 160 students who have completed a total of 4,845 team experiments during the past three spring semesters, put theory to the experimental test, patiently uncovered errors, diligently provided instant feed back, and ultimately must be credited with imparting life to the program. It is a pleasure to cite each of the following students for his contributions to the APL curriculum:

APL 1967

M. Abreu
R. Abreu
V. Albit
G. Alcorta
M. Alvarez
C. Atkins, Jr.
I. Bauland
D. Berlingieri
G. Blanchard
E. Campbell
R. Cater
R. Chernick
G. Chin
T. Chin
J. Colon
A. Dames
A. Dickerson
J. Eiche
D. Eng
A. Firestone
S. Gancasz
A. Gee
C. Giordano
G. Grossi
E. Hang
N. Jaremko
S. Jung
P. Lai
S. Lane
C. Lee
L. Ma
M. Martinez
R. Mercurio
J. Montalvo
G. Neumann
R. Nizza
W. Poy
M. Punziano
P. Raanan
T. Rogers
P. Romeo
R. Santiago
E. Schiavone
M. Schulman
A. Seibold
H. Soohoo
G. Terlecki
W. Tow
J. Vasquez
W. Walenta
S. Wan
J. Wu

APL 1968

L. Archetti
W. Ben
L. Bisonni
P. Borkowski
M. Caballero
J. Chin
J. Clark
J. Comunale
M. Czarny
N. Decanditis
M. Delerme
G. DeLisser
R. Durante
A. Eng
W. Grabe
J. Graff
J. Grassi
P. Hadatschi
C. Haden
K. James
C. Kalinoski
B. Keels
D. Krzyzewski
P. Leon
J. Lew
S. Mark
J. Martinez
J. Masefield
T. Masser
A. Masterpalo
M. McCrawford
J. Milani
P. Moy
P. Moy
P. Muller
A. Nachajski
M. Nadler
A. Negron
G. Nizza
H. Opdal
P. Parisi
R. Peterson
M. Powell
R. Quinones
W. Rao
R. Reiss
R. Rodriguez
L. Rojas
T. Rosa
R. Sanchez
G. Sardis
R. Seissian
J. Torres
J. Trabazo
D. Vaudo
R. Villavasso
S. Whing
M. Yu

APL 1969

C. Abrams
N. Bisonni
M. Cannizzo
R. Caro
R. Carter
T. Cheung
M. Countouroudas
C. Crisafulli
K. Eng
R. Faur
W. Federowiczs
J. Fischer
T. Fischer
J. Gagnon
L. Goodman
F. Hager
B. Hajdukiewicz
L. Horowitz
J. Irizzary
M. Jaszcar
J. Johnson
J. King
B. Kiljanski
J. Kubik
R. Kulesha
G. Kump
F. Lee
L. Lopez
G. Madeo
A. Mora
R. Martinez
A. Mateo
J. McKenna
J. Mundo, Jr.
R. Nieves
M. Oppenheimer
J. Pendleton
M. Petrunia
A. Riddick
H. Rodriguez
M. Rodriguez
R. Rodriguez
A. Roxo
T. Smith
A. Solomon
W. Tam
J. Weiss
J. Weston
L. White
J. Zlata

EPILOGUE

The APL curriculum was originally intended to be an opportunity in advanced study for high school seniors who, with few exceptions, had completed the usual high school physics course. Previously cited evidence that 9 out of 10 graduates of APL 1967 continue successfully at the City College School of Engineering amply demonstrates the value of the high school program they selected. However, at Aviation High School there exists a long tradition of commencing full time work in industry immediately after graduation. With more and more students making commitments to higher education, a serious problem has developed for the "borderline" pupil--who shall be defined as one who can probably succeed in college but fears that concentration on college preparation may jeopardize his chances to learn a trade and yet not assure success in college. Restated, the dilemma is this: if he does not focus his efforts on academic preparation he will probably not go on to college or if he should change his mind about college entrance after graduation his chances for success diminish because no prior effort was made to improve his "borderline" status.

With this in mind, Aviation High School anticipates expanding the APL program for the coming year from one semester to two semesters. The conventional APL curriculum will be offered for the first time during the fall semester and except for a few minor modifications will follow the regular experiment sequence. The last experiment #91 "Semiconductors and Rectifiers" will serve as an introduction to a basic series of electronic and transistor experiments to begin during February 1970. Augmenting previous studies at Aviation with this new and practical experience in the rapidly expanding field of solid state physics should reassure the student that his opportunities for employment have been enhanced.

The experiences shared by classmates in 120 different experiments will serve as a firm foundation upon which to build a sound intuitive and physical approach to the calculus, in the laboratory itself, during the remaining three months of the year. Morris Kline's Calculus will set the pace for the class, but emphasis would be placed on preparing for the college calculus course rather than trying to replace it. Any attempt to teach a college calculus course in high school to a pupil who is expected to have trouble with such a course in college is destined for failure since it unwisely makes the student meet the difficulty sooner, and at a time when he is less prepared. Breaking the educational lockstep with the double period (90 minutes daily) and with an instructor who intimately knows the strengths and weaknesses of his pupils after observing their encounters with 120 experiments, increases the probability of success with "borderline" students. At Aviation, to borrow a phrase, the calculus will be pursued with more vigor and less rigor.

In the future, special consideration will be given to students who have been unable to pass the traditional physics course and the Regents' examination which comes after a full year of study. If they wish, they will get another chance to meet physics under pleasanter

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In the future, special consideration will be given to students who have been unable to pass the traditional physics course and the Regents' examination which comes after a full year of study. If they wish, they will get another chance to meet physics under pleasanter circumstances in the laboratory. The one shot examination is a wonderful incentive for some students, but it is discouraging, oppressive, and self-defeating for youngsters with weak backgrounds, poor study habits, and/or language difficulties, and who have only recently raised their aspirational levels.

At Aviation High School, experimentation is interminable. In the words of Winston Churchill: "This is not the end. It is not even the beginning of the end. It is rather the end of the beginning."

Experiment Sequence

Spring 1969

(Feb. 4)

1. Review Physics - Films
2. Survey Library
3. Triangulation
4. Indirect Measurement
5. Approx. Areas
6. Approx. Volumes
7. Density - Regular, Irregular
8. Density - Lighter than Water, Liq.
9. Direct & Indirect Time Measurements
10. Make and Use Vernier

(Feb. 12)

11. Height Gauge & Dial Indicator
12. Length of Molecule
13. Constants of Proportionality
14. Pendulum I
15. Pendulum II (Foucault)
16. Construct Slide Rule
17. Apply Slide Rule
18. g and the Inclined Plane
19. Written Report
20. Absolute Zero

(Feb. 26)

21. Direct Measurement of g
22. Pendulum Velocity & Acceleration
23. Atwood's Machine
24. Newton's 2nd Law
25. Hooke's Law
26. Force Vectors
27. Centripetal Force
28. Centripetal Force & Acceleration
29. Written Report
30. Momentum

(Mar. 12)

31. g via Pendulum & Atwood
32. Pulley IMA
33. Coefficient of Friction I
34. " " II
35. M.A. and Efficiency
36. Water & Atmospheric Pressure
37. Boyle's Law
38. Projectiles

(Apr. 16)

51. Drag vs. Shape & Speed
52. Lift vs. Speed & Angle of Attack
53. Ohmmeter
54. Circuit Resistance
55. Ohm's Law
56. Resistance via V-A Method
57. Factors in Wire Resistance
58. Non-Linear Resistance
59. Kirchhoff's 1st Law
60. Kirchhoff's 2nd Law

(Apr. 30)

61. Analyzing Ckt. via Voltmeter
62. Trouble Shooting via Symptoms
63. Wheatstone Bridge
64. Design & Construct Voltmeter
65. Design & Construct Switching Ckts.
66. Design & Construct Ohmmeter
67. Networks & Simultaneous Equations
68. π and T Transformations
69. Kirchhoff's Laws Applied
70. Electricity-Heat Energy Conversion

(May 14)

71. Electrical Resistance & Temp. Coeff.
72. Impedance Matching
73. Thevenin's Theorem
74. L Pads and Curves
75. Lenz's Law and Transformers
76. Magnets & Inverse Square Law
77. Int. to Oscilloscope
78. Ionic Charge
79. Earth's Magnetic Field
80. Coil Magnetic Induction

(May 28)

81. Determine Electron Mass
82. Synchro Systems
83. RC Constant
84. Relaxation Oscillator
85. Vectors & Capacitive Reactance
86. Factors in Capacitive Reactance
87. Inductive Reactance
88. Series Circuit

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3. Triangulation
4. Indirect Measurement
5. Approx. Areas
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8. Density - Lighter than Water, Liq.
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(Mar. 12)

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32. Pulley IMA
33. Coefficient of Friction I
34. " " II
35. M.A. and Efficiency
36. Water & Atmospheric Pressure
37. Boyle's Law
38. Projectiles
39. Trajectories
40. Torricelli's Law

(Mar. 26)

41. Manometer & Venturi Tube
42. Wind Speed
43. Calibrate Torque Wrench
44. Center of Gravity I (Airplane)
45. Center of Gravity II
46. Analytic Balance
47. Pile Driver
48. Spring Vibration & SHM
49. Satellite Orbits & Inv. Sq. Law
50. Locate Satellites in Space

51. Drag vs. Shape & Speed
52. Lift vs. Speed & Angle of Attack
53. Ohmmeter
54. Circuit Resistance
55. Ohm's Law
56. Resistance via V-A Method
57. Factors in Wire Resistance
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78. Ionic Charge
79. Earth's Magnetic Field
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(May 28)

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82. Synchro Systems
83. RC Constant
84. Relaxation Oscillator
85. Vectors & Capacitive Reactance
86. Factors in Capacitive Reactance
87. Inductive Reactance
88. Series Circuit Resonance
89. Parallel Circuit Resonance
90. Frequency Measurement

(June 13)

91. Semiconductors and Rectifiers
92.
93.
94.
95.
96.
97.
98.
99.
100.

Station | Exp. # 1 | Team

AVIATION HIGH SCHOOL — APPLIED PHYSICS LABORATORY

> "A picture is worth more than a thousand words."
>
> Chinese Proverb
>
> "What a vanity is painting, which attracts admiration by the resemblance of things that in the original we do not admire!"
>
> Blaise Pascal
>
> "A thousand words will not leave so deep an impression as one deed."
>
> Henrik Ibsen

PROBLEM: To review physics--mechanics using film strips.

APPARATUS:

Film viewer
Special AC plug
120v. AC Table supply

REFERENCES:

1. Dull, Modern Physics
2. Stollberg, Physics Fundamentals and Frontiers
3. White, Modern College Physics

FILMS:

1.	3042	Measurements and Measuring I
2.	3043	" " " II
3.	3044	Units of Measurement
4.	3004	Physics Principles
5.	3005	" "
6.	3013	Laws of Motion
7.	3014	Newton's Laws of Motion
8.	3006	Force and Velocity as Vectors
9.	3008	Vectors -- Directed Quantities
10.	3007	Centripetal force
11.	3009	Universal Gravitation
12.	3010	Moments of Force and Torque
13.	3012	Conservation of Momentum
14.	3018	Dynamics -- Bodies in Motion
15.	3027	Energy
16.	3031	Machines
17.	3041	Scientific Measurement

GATHERING THE DATA:

1. Connect film viewer to AC table supply using special plug.
2. Insert a film of special interest.
3. Scan entire film.
4. Review film as follows:
    a) List film title ex. Laws of Motion (3013)
    b) List key definitions, ideas, and principles (according to frame number if possible--add pertinent comments).
        Ex. Frame #5 Newton's First Law of Motion
        Conditions: $\Sigma F_x = 0$; $\Sigma F_y = 0$
    c) Answer questions in film strips.
        Ex. Frame #32 If mass of 1000 kg is given an acceleration of 10 meters per second per second, what is the force?
        $F = ma = 1000\text{ kg} \times \frac{10\text{m}}{\text{sec}^2} = 10{,}000$ newtons

Blaise Pascal

> "A thousand words will not leave so deep an impression as one deed."
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SUMMATION:

1. Which topic was of most interest? Why?
2. Which film was the most difficult to comprehend? Why?
3. List advantages - if any - of color film over black and white film.
4. Can a student learn physics via film alone? Explain.
5. Was this film viewing experience worthwhile? Explain.
6. If possible, suggest a better way to review physics in a short period of time? Justify.

Station

AVIATION HIGH SCHOOL

Exp. # 2

APPLIED PHYSICS LABORATORY

Team

> "Books are masters who instruct us without rods...or anger... If you approach them, they are not asleep; if you seek them, they do not hide; if you blunder, they do not scold; if you are ignorant, they do not laugh at you."
>
> Richard de Bury
>
> "Books...are ready to repeat their lessons as often as we please."
>
> Chambers

PROBLEM: To survey the APL library.

APPARATUS:

REFERENCES:

The APL library.

BACKGROUND:

According to Nathan Grier Parke III in his Guide to the Literature of Mathematics and Physics:

> "It is economical of time and mental energy to make a general survey of a book before becoming immersed in its details."....
>
> "The preface gives more of a clue to the author's feelings, outlook, and aim than any other part of the book. In the preface will be found the following kinds of remarks:
>
> Purpose of the book
> Prerequisites
> Intended class of readers
> Apologies
> Delineation of the subject matter
> Chapter-by-Chapter comments
> Pedagogical aims
> Novel features
> Historical remarks
> Warnings
> Hints about the reading order
> Philosophical digressions
> Acknowledgements and thanks
> Origin of the book"

GATHERING THE DATA:

1. Browse through the available books.
2. Arbitrarily decide upon an order of inspection and then report on each book as follows:
   a) List Author's last name, Initials, Book Title
   Publisher, City, Date.

   ex. Holton, G., Foundations of Modern Physical Science
   Addison-Wesley Pub. Co., Inc., Reading, Mass., 1958

   b) Read the preface, examine the table of contents, explore the index, and scan the book.

   c) Use Parke's preface observations as a frame on which to build your brief report.

"Books...are ready to repeat their lessons as often as we please."
Chambers

PROBLEM: To survey the APL library.

APPARATUS:

REFERENCES:

The APL library.

BACKGROUND:

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    c) Use Parke's preface observations as a frame on which to build your brief report.

SUMMATION:

1. Categorize the books according to mathematical prerequisites.
2. Categorize the books according to below, on, or above high school level. Do the mathematical prerequisites provide a good basis for making these distinctions?
3. Which books approach their topics from an historical point of view?
4. Which three books do you consider (at this stage) to be the most informative and useful? Why?

Station 51 Exp.# 3 Team

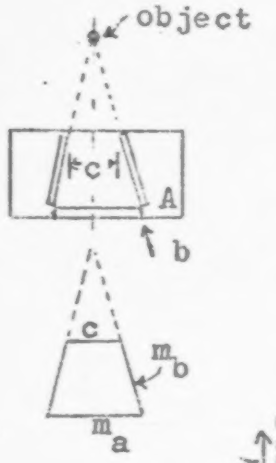
AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "The spirit of generalization should dominate a university (and a laboratory)... During the school period the student has been mentally bending over a desk; at the university (and the laboratory) he should stand up and look around."
>
> Alfred N. Whitehead

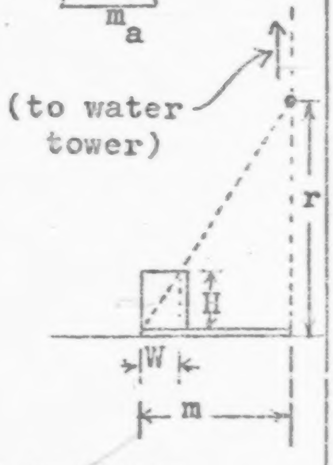
PROBLEM: To measure the ranges and dimensions of distant objects.

APPARATUS:	REFERENCES:
3 meter sticks	1. Stollberg & Hill, Physics, pp.561-2
Paper	
Split image range finder	2. PSSC, Physics, pp. 24-27

GATHERING THE DATA:

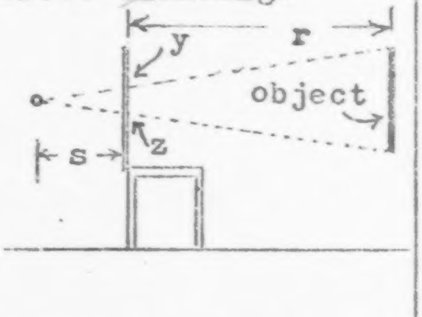


1. a) Place meter stick along edge of lab. table such that its center is in line with object at window.
   b) From ends of meter stick, sight along two other meter sticks to the target as shown.
   c) Measure distance c between meter sticks.
   d) Using similar triangles, determine distance from point A to object. (Show calculations)
   e) Directly measure distance to object and compare with results due to triangulation.

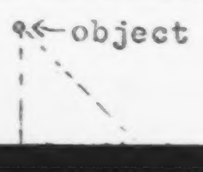


2. Measure distance to object using parallax.
   a) Place meter stick along edge of lab. table such that an end is in line with the object and a distant reference point--the Big Six water tower.
   b) Place sheet of paper at other end of meter stick and draw sighting line to the object on paper as shown.
   c) Note that sighting to the Big Six water tower is still perpendicular to the meter stick. (Why isn't this apparent on the adjacent sketch?)
   d) Calculate distance to object using similar triangles.

3. Using parallax method, measure distance to sign on 40 Street building.



4. Determine the height of the object at the window.
   a) Mount meter stick vertically at edge of lab. table.
   b) Stand approx. 1 meter from the meter stick (carefully measuring this distance) and note readings y and z on meter stick.
   c) Use data of steps #1 and #2 to determine distance r and then calculate height of object using similar triangles--show calculations.



5. Calibrate split image range finder with objects at known distances.
   a) Position range finder so that an object appears directly above the fixed mirror.
   b) Adjust arm so that the image of the object in the movable mirror appears in the fixed mirror direct-

PROBLEM: To measure the ranges and dimensions of distant objects.

APPARATUS:

3 meter sticks
Paper
Split image range finder

REFERENCES:

1. Stollberg & Hill, Physics, pp. 561-2
2. PSSC, Physics, pp. 24-27

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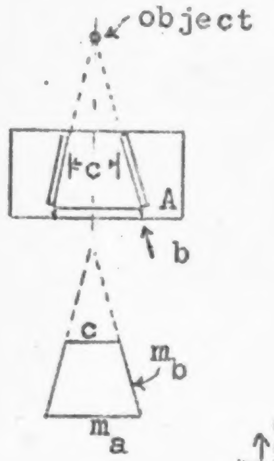

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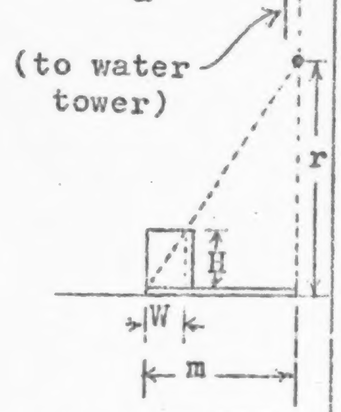
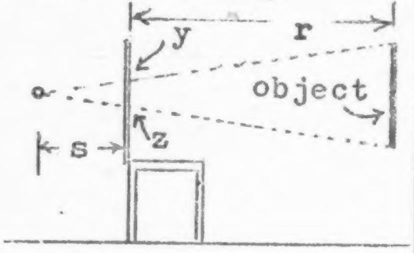
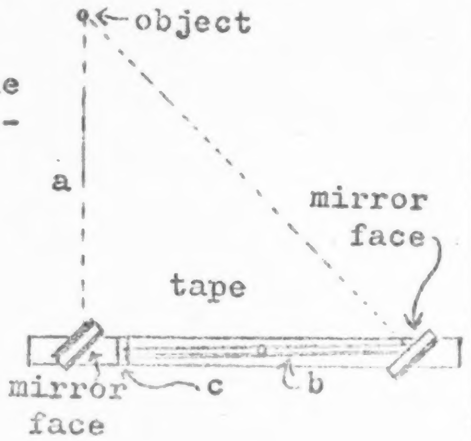
   d) Calculate distance to object using similar triangles.



3. Using parallax method, measure distance to sign on 40 Street building.
4. Determine the height of the object at the window.
   a) Mount meter stick vertically at edge of lab. table.
   b) Stand approx. 1 meter from the meter stick (carefully measuring this distance) and note readings y and z on meter stick.
   c) Use data of steps #1 and #2 to determine distance r and then calculate height of object using similar triangles--show calculations.

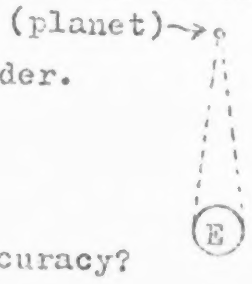


5. Calibrate split image range finder with objects at known distances.
   a) Position range finder so that an object appears directly above the fixed mirror.
   b) Adjust arm so that the image of the object in the movable mirror appears in the fixed mirror directly below the object itself.
   c) Place mark on tape and label with appropriate distance.
   d) Repeat a through c for other objects at known distances.
   e) Use split image range finder to measure the distances to various objects in the laboratory.



SUMMATION:

1. Is method #1 above better for short or long distances? Explain.
2. In step #3 the parallax reference point does not seem to enter the calculations. Explain.
3. Explain the geometrical optics of the split image range finder. Use labeled sketches.
4. Explain how the parallax method can be used to measure the distance to a planet.
5. Will the use of a base larger than a meter stick improve accuracy?



Station ⬡ Exp.# 4 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "I often say that when you can measure what you are speaking about, and express it in numbers you know something about it; but when you cannot express it in numbers, your khowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science, whatever the matter may be."
>
> Lord Kelvin

PROBLEM: To make indirect measurements.

APPARATUS:

Triple beam balance	Meter stick
#10 washers	Spheres
½" x #20 wire brads	Box of BB's
10ml grad. cylinder	Liter & Pint
Medicine dropper	Square blocks
2" x 10/32 nut & bolt	Graph paper

REFERENCES:

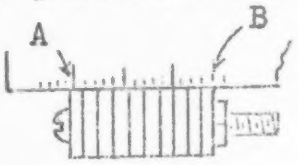
BACKGROUND:

If in measuring a thickness of .16" an error of .01" occurs, then an error of .01"/.16" = 6% has been made.

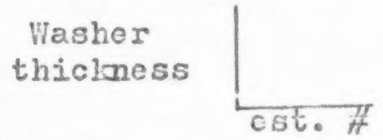
But, if an error of .01" is made when measuring six .16" thicknesses stacked together then the error is only one of 1%.

GATHERING THE DATA:

1. a) Measure washer thickness with meter stick (estimate to part of a mm).
   b) Measure washer thickness by measuring more than one:
   c) Record data in table:

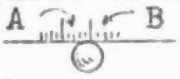


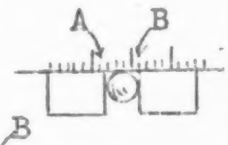
Trial	# of stacked washers	B-A	Thickness/washer
1	5		
2	10		



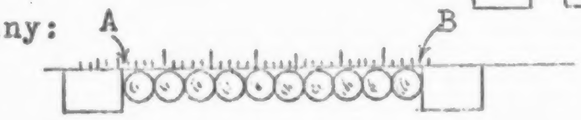
2. a) Measure thickness of single sheet of paper in White's Mod. Coll. Physics.
   b) Estimate paper thickness by measuring 100, 200, 300 sheets, ...
   c) Tabulate data in table.
   d) Repeat for Radio Electronic Master sheet.

3. a) Measure sphere diameter. b) Repeat using square blocks.

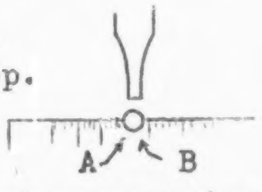




   c) Measure sphere diameter by measuring many:



4. Determine volume of a drop of water.
   a) Estimate diameter of falling drop.
   b) Calculate volume $V = \frac{4\pi r^3}{3}$



5. a) Determine volume of drop of water by measuring the number of drops in 1 ml.
   b) Repeat for 2, 3, 4, ... 10 ml.
   c) Record data.

but you have scarcely in your thoughts advanced to the stage of science, whatever the matter may be."

Lord Kelvin

PROBLEM: To make indirect measurements.

APPARATUS:

REFERENCES:

Triple beam balance	Meter stick
#10 washers	Spheres
½" x #20 wire brads	Box of BB's
10ml grad. cylinder	Liter & Pint
Medicine dropper	Square blocks
2" x 10/32 nut & bolt	Graph paper

BACKGROUND:

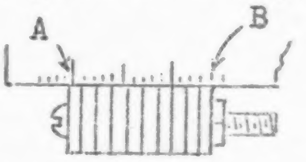
If in measuring a thickness of .16" an error of .01" occurs, then an error of .01"/.16" = 6% has been made.

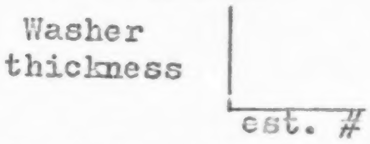
But, if an error of .01" is made when measuring six .16" thicknesses stacked together, then the error is only one of 1%.

GATHERING THE DATA:

1. a) Measure washer thickness with meter stick (estimate to part of a mm).
   b) Measure washer thickness by measuring more than one:
   c) Record data in table:

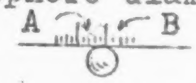
Trial	# of stacked washers	B-A	Thickness/washer
1	5		
2	10		



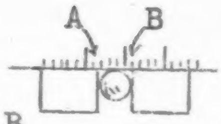


2. a) Measure thickness of single sheet of paper in White's Mod. Coll. Physics.
   b) Estimate paper thickness by measuring 100, 200, 300 sheets, ...
   c) Tabulate data in table.
   d) Repeat for Radio Electronic Master sheet.

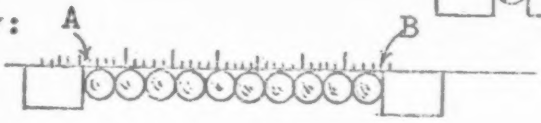
3. a) Measure sphere diameter.



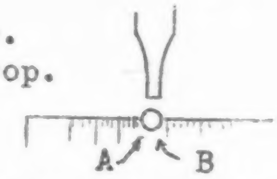
   b) Repeat using square blocks.



   c) Measure sphere diameter by measuring many:



4. Determine volume of a drop of water.
   a) Estimate diameter of falling drop.
   b) Calculate volume $V = \frac{4\pi r^3}{3}$



5. a) Determine volume of drop of water by measuring the number of drops in 1 ml.
   b) Repeat for 2, 3, 4, ... 10 ml.
   c) Record data.
   d) Experimentally determine the number of drops in one pint: in one liter.

6. a) Measure the mass of one 1/2" brad.
   b) Measure mass of brad, using average of more than one.
   c) Record data.
   d) Experimentally determine the number of brads in the box.

SUMMATION:

1. Which sheet of paper was measured more accurately in step #2 above? Why?
2. Give reasons why successive measurements of the same sphere in step #3 above differ.
3. Using data of step #5, what is the best estimate of the diameter of a water drop? Explain.

Station ⬡ AVIATION HIGH SCHOOL Exp. # 5 APPLIED PHYSICS LABORATORY Team ○

> "...the book of nature...is written only in the mathematical language and the symbols are triangles, circles, and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth."
>
> Galileo

PROBLEM: To experimentally approximate areas.

APPARATUS:
1/4" graph paper Geometric Figures
1/10" graph paper Steel rule
Ohaus triple beam balance

REFERENCES:
1. Handbook of Chemistry & Physics
2. Thomas Calculus & Analytic Geometry pp. 191-195

GATHERING THE DATA:

1. a) Randomly place the rectangle on the 1/4" graph paper.
   b) With a sharp pencil, carefully trace the rectangle shape on the graph paper.
   c) Count the complete squares contained within the rectangular form.
   d) Count the incomplete squares which are half or more than half within the rectangle's boundaries.
   e) Add the numbers counted in c and d, calculate the area of the rectangle, and insert result in table.
2. Repeat step #1 using 1/10" graph paper.
3. Measure the sides of the rectangle and calculate area using formula.
4. Repeat steps 1, 2, and 3 for the following objects:

Object	1/4" area	1/10" area	Formula area	Area via mass
Right triangle				
Isosceles triangle				
Equilateral triangle				
Obtuse triangle				
Parallelogram				
Trapezoid				
Quadrilateral (irregular)				
Hexagon				
Octagon				
Irregular Polygon				
Circle				
Irregular shape				

5. Measure the mass of the rectangle.
6. Measure the mass of each object and determine its area using:

$$\text{area of object} = \frac{(\text{area of rectangle}) \times (\text{mass of object})}{(\text{mass of rectangle})}$$

SUMMATION:

1. Compare 1/10" and 1/4" graph paper results. Which is more accurate? Why?
2. Discuss the advantages of placing a regular geometric figure symmetrically

PROBLEM: To experimentally approximate areas.

APPARATUS:
1/4" graph paper Geometric Figures
1/10" graph paper Steel rule
Ohaus triple beam balance

REFERENCES:
1. Handbook of Chemistry & Physics
2. Thomas Calculus & Analytic Geometry pp. 191-195

GATHERING THE DATA:

1. a) Randomly place the rectangle on the 1/4" graph paper.
   b) With a sharp pencil, carefully trace the rectangle shape on the graph paper.
   c) Count the complete squares contained within the rectangular form.
   d) Count the incomplete squares which are half or more than half within the rectangle's boundaries.
   e) Add the numbers counted in c and d, calculate the area of the rectangle, and insert result in table.
2. Repeat step #1 using 1/10" graph paper.
3. Measure the sides of the rectangle and calculate area using formula.
4. Repeat steps 1, 2, and 3 for the following objects:

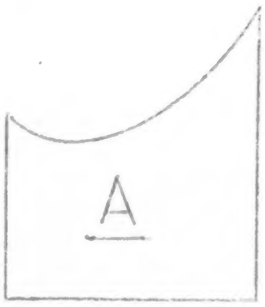
Object	1/4" area	1/10" area	Formula area	Area via mass
Right triangle				
Isosceles triangle				
Equilateral triangle				
Obtuse triangle				
Parallelogram				
Trapezoid				
Quadrilateral (irregular)				
Hexagon				
Octagon				
Irregular Polygon				
Circle				
Irregular shape				

5. Measure the mass of the rectangle.
6. Measure the mass of each object and determine its area using:

$$\text{area of object} = \frac{(\text{area of rectangle}) \times (\text{mass of object})}{(\text{mass of rectangle})}$$

SUMMATION:

1. Compare 1/10" and 1/4" graph paper results. Which is more accurate? Why?
2. Discuss the advantages of placing a regular geometric figure symmetrically on a set of perpendicular axes.
3. Justify, mathematically, the equation used in step #6 above.
4. Under what conditions can the mass-area method be used? Were these conditions met in this experiment?
5. Explain how you could determine the area of figure A.
6. What kind of mathematics can be used to determine the area of figure A?
7. Of the area methods used, which one do you prefer? Why?



Station ⬡ Exp. # 6 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Proof is an idol before whom the pure mathematician tortures himself. In physics we are generally content to sacrifice before the lesser shrine of plausibility."
>
> A. Eddington

PROBLEM: To calculate and to experimentally approximate volumes.

APPARATUS:

Geometric Solids Balance
Buret and funnel 500 cc beaker
6" metric rule Medicine dropper
Metric micrometer
Support stand & buret clamp
25 & 50 ml graduated cylinders

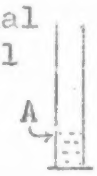
REFERENCES:

1. Handbook of Chemistry & Physics
2. Encyclopaedia Britannica (see--mensuration)
3. Thomas, Calculus pp. 996-7

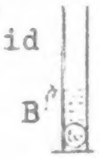
GATHERING THE DATA:

1. Check volume of each solid by water displacement. Use most accurate method

a) check original water level

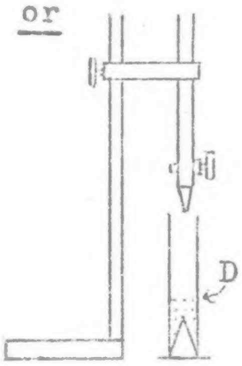


b) check level after solid has been inserted



(insert results in table)

or



a) add accurately measured water from buret. C

until water level reaches easily read mark on grad. cylinder volume = D-C

2. Accurately measure solids and calculate their volumes according to formula.
3. Measure the mass of the cube, and use its easily calculated volume to determine the volumes of the other solids as follows:

$$\text{volume of solid} = \frac{(\text{vol. of cube}) \times (\text{mass of solid})}{(\text{mass of cube})}$$

4. Repeat steps #1, 2, and 3 for each object and insert results in table:

Geometric Solid	Vol. by Displacement	Vol. by Formula	Vol. by Mass
Cube			
Square Prism			
Rectangular Prism			
Rt. Angled Triangle Prism			
Equilateral Triangle Prism			
Hexagonal Prism			
Octagonal Prism			
Cylinder			
Sphere			
Hemisphere			
Truncated Cylinder			
Cone			
Frustum of a Cone			
Truncated Cone			
Pyramid			
Tetrahedron			
Octahedron			
Dodecahedron			
Icosahedron			

PROBLEM: To calculate and to experimentally approximate volumes.

APPARATUS:

Geometric Solids
Buret and funnel
6" metric rule
Metric micrometer
Support stand & buret clamp
25 & 50 ml graduated cylinders
Balance
500 cc beaker
Medicine dropper

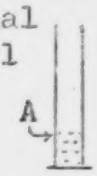
REFERENCES:

1. Handbook of Chemistry & Physics
2. Encyclopaedia Britannica (see--mensuration)
3. Thomas, Calculus pp. 996-7

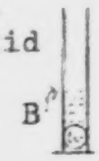
GATHERING THE DATA:

1. Check volume of each solid by water displacement. Use most accurate method

a) check original water level

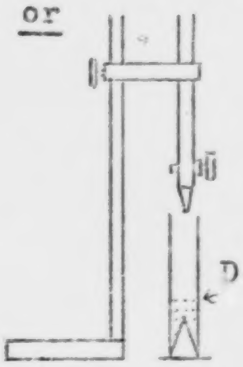


b) check level after solid has been inserted



(insert results in table)

or



a) add accurately measured water from buret. C

until water level reaches easily read mark on grad. cylinder volume = D-C

2. Accurately measure solids and calculate their volumes according to formula.

3. Measure the mass of the cube, and use its easily calculated volume to determine the volumes of the other solids as follows:

$$\text{volume of solid} = \frac{(\text{vol. of cube}) \times (\text{mass of solid})}{(\text{mass of cube})}$$

4. Repeat steps #1, 2, and 3 for each object and insert results in table:

Geometric Solid	Vol. by Displacement	Vol. by Formula	Vol. by Mass
Cube			
Square Prism			
Rectangular Prism			
Rt. Angled Triangle Prism			
Equilateral Triangle Prism			
Hexagonal Prism			
Octagonal Prism			
Cylinder			
Sphere			
Hemisphere			
Truncated Cylinder			
Cone			
Frustum of a Cone			
Truncated Cone			
Pyramid			
Tetrahedron			
Octahedron			
Dodecahedron			
Icosahedron			
Ellipsoid			
Oblate Spheroid			

SUMMATION:

1. Which method for volume determination was preferred? Why?

2. What conditions must be met before the mass-volume method is applicable? Were these conditions met in this experiment?

3. Which water displacement method was most accurate? Why?

Station

Exp. # 7

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Science is clearly a way of solving problems--not all problems, but a large class of important and practical ones. The problems with which it can deal are those in which the predominant factors are subject to the basic laws of logic and are for the most part measurable."
>
> — Warren Weaver

PROBLEM: To determine the densities of regular and irregular objects.

APPARATUS:

Graduated cylinders	6" metric rule
Test specimens	500 cc beaker
Medicine dropper	
Triple beam balance	

REFERENCES:

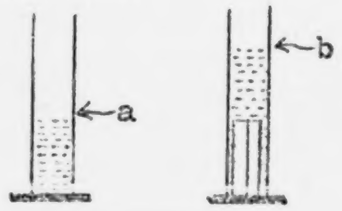
1. Taffel, Visualized Physics, pp. 6-7
2. Stollberg, Physics Fundamentals, pp. 202-3
3. White, Modern College Physics, p. 185
4. CRC, Handbook of Physics and Chemistry

GATHERING THE DATA: (DO NOT DROP OBJECTS THROUGH GRADUATED CYLINDERS)

1. Determine the densities of regular objects, by taking their dimensions and masses and by applying geometric and density formulas.

Object	Mass	Base Area	Height	Volume	Density = M/V
A1					
A2					
etc.					

2. Determine the densities of irregular objects.
   - a) Fill appropriate graduated cylinder with water to mark a.
   - b) Insert irregular object and note new water level b.
   - c) Insert data in table and calculate density.



Object	Mass	Vol. b	Vol. a	Object's Volume	Density = M/V
B1					
B2					
etc.					

3. a) Determine the density of small objects, using more than one to improve the accuracy of measurement.
   b) Identify materials using density table.

Objects	Number	Mass	Volume	Density	Material	Table Density
washers						
nuts						
rivets						

Warren Weaver

PROBLEM: To determine the densities of regular and irregular objects.

APPARATUS:

Graduated cylinders
Test specimens
Medicine dropper
Triple beam balance
6" metric rule
500 cc beaker

REFERENCES:

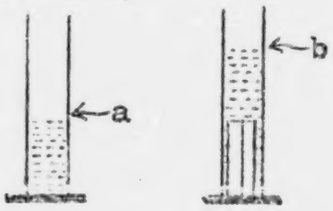
1. Taffel, *Visualized Physics*, pp. 6-7
2. Stollberg, *Physics Fundamentals*, pp. 202-3
3. White, *Modern College Physics*, p. 185
4. CRC, *Handbook of Physics and Chemistry*

GATHERING THE DATA: (DO NOT DROP OBJECTS THROUGH GRADUATED CYLINDERS)

1. Determine the densities of regular objects, by taking their dimensions and masses and by applying geometric and density formulas.

Object	Mass	Base Area	Height	Volume	Density = M/V
A1					
A2					
etc.					

2. Determine the densities of irregular objects.
   a) Fill appropriate graduated cylinder with water to mark a.
   b) Insert irregular object and note new water level b.
   c) Insert data in table and calculate density.



Object	Mass	Vol. b	Vol. a	Object's Volume	Density = M/V
B1					
B2					
etc.					

3. a) Determine the density of small objects, using more than one to improve the accuracy of measurement.
   b) Identify materials using density table.

Objects	Number	Mass	Volume	Density	Material	Table Density
washers						
nuts						
rivets						

SUMMATION:

1. Can liquids other than water be used for the displacement method? Explain.
2. What property must an object possess before the displacement method is applicable?
3. Discuss the advantages and disadvantages of the displacement method for measuring volumes and densities.
4. Using the density equation and the triple beam balance, determine the volumes of the irregular metal sheets.

Sheet	Mass	Table Density	Volume
aluminum			
bronze			
zinc			

Station ⬡ **AVIATION HIGH SCHOOL** Exp.# 8 **APPLIED PHYSICS LABORATORY** Team ○

> "Whenever anything does not succeed the first time, the student should try it again; but he should not try thoughtlessly, on the mere chance of better luck next time: he should endeavor by careful consideration to find out the cause of his ill success."
>
> Adolf Weinhold

PROBLEM: To determine the density of irregular objects lighter than water and to determine the densities of liquids.

APPARATUS:

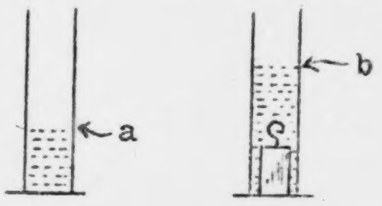
- Graduated cylinders
- Test specimens
- Gram "wt" set
- Triple beam balance
- Medicine dropper
- 500 cc beaker
- Funnel
- Paper towels

REFERENCES:

1. Taffel, Visualized Physics, pp. 6-7, 14-16
2. White, Modern College Physics, pp. 187-8
3. CRC, Handbook of Chemistry and Physics

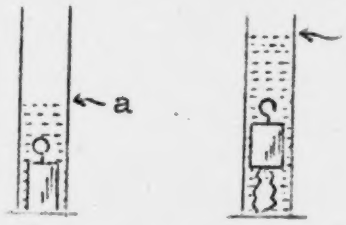
GATHERING THE DATA:

1. Determine the densities and volumes of several standard masses:



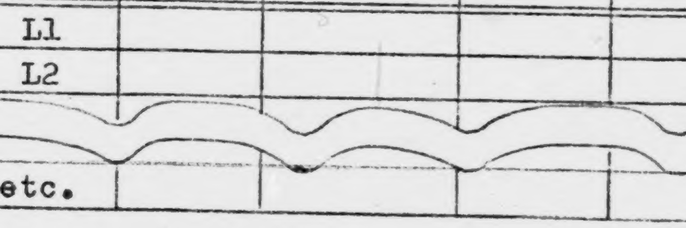
Mass	Vol. b	Vol. a	Object Vol.	Density = M/V
500gm				
200gm				
100gm				

2. Determine the densities of objects lighter than water:



Object	Vol. b	Vol. a	Volume	Mass	Density = M/V
W1					
W2					
etc.					

3. Determine the densities of liquids:



(thoroughly clean out grad. cylinder with detergent after each test--rinse thoroughly and dry)

Liquid	Total Mass	Cylinder Mass	Liquid Mass	Liquid Volume	Density = M/V
L1					
L2					
etc.					

Adolf Weinhold

PROBLEM: To determine the density of irregular objects lighter than water and to determine the densities of liquids.

APPARATUS:

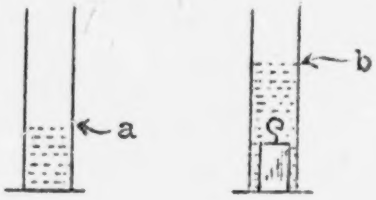
Graduated cylinders
Test specimens
Gram "wt" set
Triple beam balance
Medicine dropper
500 cc beaker
Funnel
Paper towels

REFERENCES:

1. Taffel, Visualized Physics, pp. 6-7, 14-16
2. White, Modern College Physics, pp. 187-8
3. CRC, Handbook of Chemistry and Physics

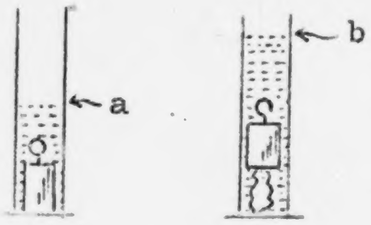
GATHERING THE DATA:

1. Determine the densities and volumes of several standard masses:



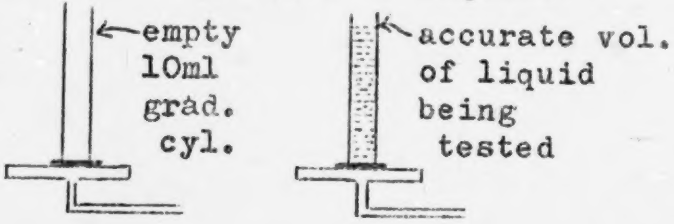
Mass	Vol. b	Vol. a	Object Vol.	Density = M/V
500gm				
200gm				
100gm				

2. Determine the densities of objects lighter than water:



Object	Vol. b	Vol. a	Volume	Mass	Density = M/V
W1					
W2					
etc.					

3. Determine the densities of liquids:



(thoroughly clean out grad. cylinder with detergent after each test--rinse thoroughly and dry)

Liquid	Total Mass	Cylinder Mass	Liquid Mass	Liquid Volume	Density = M/V
L1					
L2					
etc.					

SUMMATION:

1. a) Determine the mass, volume, and density of the cork.
   b) Calculate the mass of a cork sphere 1 meter in diameter.
   c) Calculate the weight, in pounds, of the 1 meter diameter cork.
2. Explain how an unknown liquid can be identified via its density.
3. a) Determine the density of the liquid in the vial.
   DO NOT OPEN!!
   (Duplicate vial available for computations)
   b) Identify liquid.
4. Explain how the density of a gas can be determined.

Station

AVIATION HIGH SCHOOL

Exp.# 9

APPLIED PHYSICS LABORATORY

Team

"What then is time? If no one asks me, I know; if I want to explain it to a questioner, I do not know." St. Augustine

"Time is what happens when nothing else happens." Richard P. Feynman

PROBLEM: To make direct and indirect time measurements.

APPARATUS:

Record turn table
Iron stand & arm
Ball drop fixture
2 meter sticks
Polar coordinate & graph paper
Stop watch
Record
Steel ball
Tape

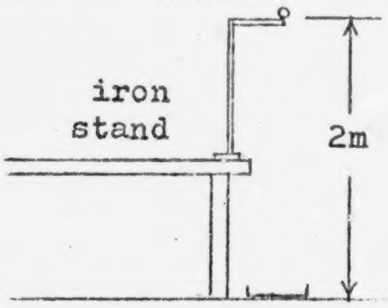
REFERENCES:

1. PSSC, Teachers Guide I

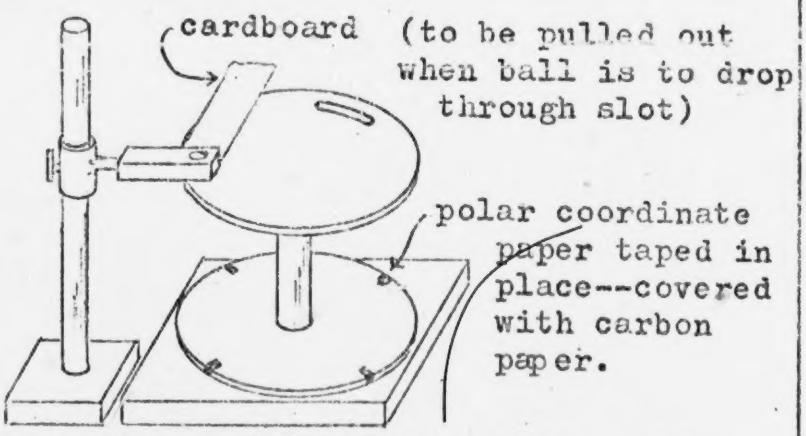
GATHERING THE DATA:

1. a) Time pulse for 20, 40, 60, 80, 100 beats--record in table.
   b) Calculate time/beat.

Pulses	Time	Time/pulse
20		
40		
100		



2. Drop steel ball 2 meters and time. (Use average of 10 trials.)
3. Drop steel ball 1 foot and time.
4. Drop steel ball 1 foot and time indirectly using record turn table and polar coordinate paper:
   a) level turn table & mount arm so that ball is free to drop through slot.
   b) tape polar coordinate paper to fixture, cover with carbon paper.
   c) rotate fixture very slowly, let ball drop and mark polar coordinate paper.
   d) reinsert a ball in arm, permit table to turn at 16RPM--check for accurate RPM with stop watch.
   e) pull out cardboard sheet just before slot--ball will drop while table turns and make an impression on polar coordinate paper indicating angle Ø through which table has turned while ball falls straight down.
   f) repeat steps b through e several times: record data in table.
   g) compute falling time: $t(\text{sec}) = \frac{\angle Ø}{360} \times \frac{60 \text{ sec.}}{(\text{actual RPM})}$


cardboard (to be pulled out when ball is to drop through slot)
polar coordinate paper taped in place--covered with carbon paper.

5. Using meter stick, stop watch, and turn table, determine the average distance between the grooves of the phonograph record.

PROBLEM: To make direct and indirect time measurements.

APPARATUS:

Record turn table
Iron stand & arm
Ball drop fixture
2 meter sticks
Polar coordinate & graph paper

Stop watch
Record
Steel ball
Tape

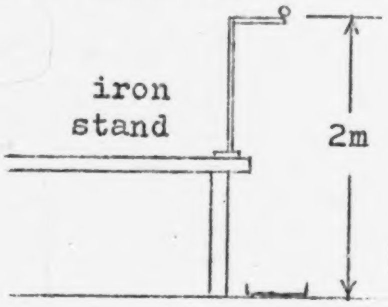
REFERENCES:

1. PSSC, Teachers Guide I

GATHERING THE DATA:

1. a) Time pulse for 20, 40, 60, 80, 100 beats--record in table.
   b) Calculate time/beat.

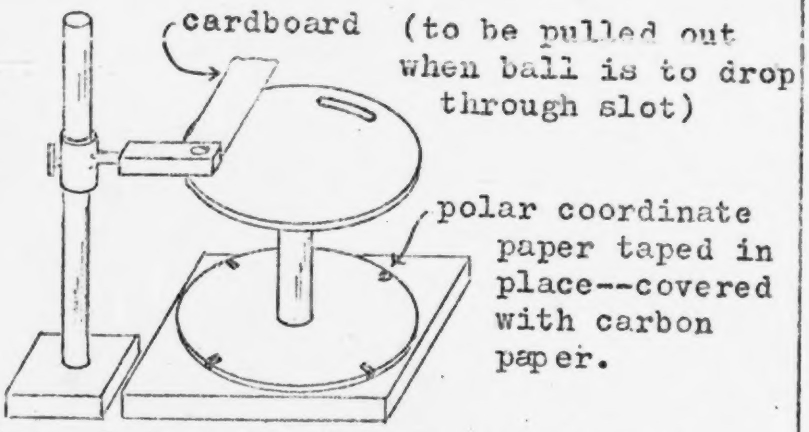
Pulses	Time	Time/pulse
20		
40		
100		



2. Drop steel ball 2 meters and time. (Use average of 10 trials.)

3. Drop steel ball 1 foot and time.

4. Drop steel ball 1 foot and time indirectly using record turn table and polar coordinate paper:
   a) level turn table & mount arm so that ball is free to drop through slot.
   b) tape polar coordinate paper to fixture, cover with carbon paper.
   c) rotate fixture very slowly, let ball drop and mark polar coordinate paper.
   d) reinsert a ball in arm, permit table to turn at 16RPM--check for accurate RPM with stop watch.



cardboard
(to be pulled out when ball is to drop through slot)
polar coordinate paper taped in place--covered with carbon paper.

   e) pull out cardboard sheet just before slot--ball will drop while table turns and make an impression on polar coordinate paper indicating angle Ø through which table has turned while ball falls straight down.
   f) repeat steps b through e several times: record data in table.
   g) compute falling time: $t(\text{sec}) = \frac{\angle \varnothing}{360} \times \frac{60 \text{ sec.}}{(\text{actual RPM})}$

5. Using meter stick, stop watch, and turn table, determine the average distance between the grooves of the phonograph record.

SUMMATION:

1. a) How consistent is pulse beat?
   b) Which of the pulse measurements is most accurate?
   c) Is the pulse beat good enough for timing velocity and acceleration of falling bodies?

2. a) Mathematically justify equation in step #4-g above.
   b) Show in detail how other turn table speeds can be used to time falling ball.
   c) For accuracy, which speed is best?

3. Explain in detail how average distance between record grooves was determined.

Station 65 Exp. # 10 Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Nothing tends so much to the advancement of knowledge as the application of a new instrument. The native intellectual powers of men in different times are not so much the causes of the different successes of their labours, as the peculiar nature of the means and artificial resources in their possession."
>
> Humphry Davy

PROBLEM: To construct a vernier and to make measurements using verniers.

APPARATUS:

Vernier micrometer
Vernier caliper
Aluminum block
Aluminum calipers
Aluminum strips
Ball bearings
Nichrome wire
White paper strip
Steel scale
Compass
Tape
Lined paper
Recessed shaft
Plug gauges
Triangle

REFERENCES:

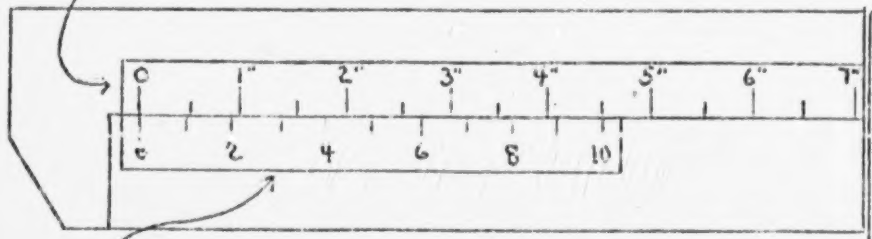
1. PSSC, *Physics*, pp. 30-1
2. Brown & Sharpe, *Catalog*
3. *Encyclopaedia Britannica*, see: vernier

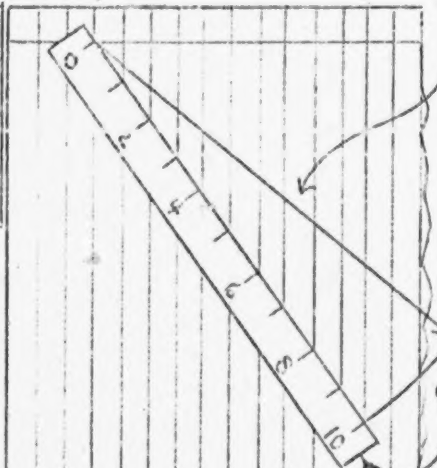
BACKGROUND:

On the micrometer vernier:
n divisions on vernier scale = (n-1) divisions on main scale
thus n (v) = (n-1) L
length of vernier division length of main scale division

PROCEDURE:

1. Make a vernier caliper
   a) tape 1/2" x 7 1/8" paper strip with carefully marked 1/2" graduations.
   b) mark off 10 spaces on lined paper.





   c) draw 4½" arc with center at beginning of 10 spaces & intersecting at end of spaces as shown.
   d) construct vernier scale as shown.
   e) tape vernier in place with zeros carefully aligned.
2. Measure aluminum strips with constructed vernier caliper and list measurements in table:

strip	inches
A	
etc.	

3. Measure ball bearing diameters with vernier micrometer. (use average of 5 measurements--each member)
4. Repeat step #3 using vernier caliper and measuring:
   a) to nearest 1/128"
   b) to nearest 0.1 mm

artificial resources in their possession."

Humphry Davy

PROBLEM: To construct a vernier and to make measurements using verniers.

APPARATUS:

- Vernier micrometer
- Vernier caliper
- Aluminum block
- Aluminum calipers
- Aluminum strips
- Ball bearings
- Nichrome wire
- White paper strip
- Steel scale
- Compass
- Tape
- Lined paper
- Recessed shaft
- Plug gauges
- Triangle

REFERENCES:

1. PSSC, Physics, pp. 30-1
2. Brown & Sharpe, Catalog
3. Encyclopaedia Britannica, see: vernier

BACKGROUND:

On the micrometer vernier:

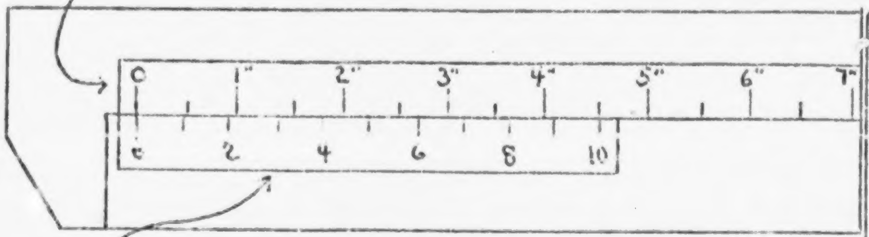
n divisions on vernier scale = (n-1) divisions on main scale

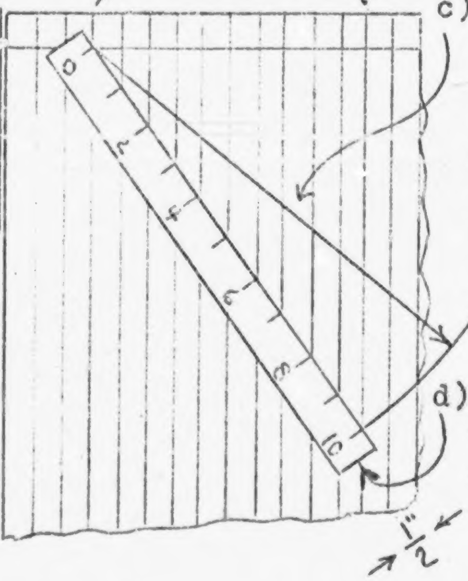
thus $n\,(v) = (n-1)\,L$

v: length of vernier division; L: length of main scale division

PROCEDURE:

1. Make a vernier caliper
   a) tape 1/2" x 7 1/8" paper strip with carefully marked 1/2" graduations.
   b) mark off 10 spaces on lined paper.

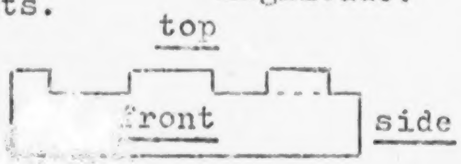




   c) draw 4½" arc with center at beginning of 10 spaces & intersecting at end of spaces as shown.
   d) construct vernier scale as shown.
   e) tape vernier in place with zeros carefully aligned.
2. Measure aluminum strips with constructed vernier caliper and list measurements in table:

strip	inches
A	
etc.	

3. Measure ball bearing diameters with vernier micrometer. (use average of 5 measurements--each member)
4. Repeat step #3 using vernier caliper and measuring:
   a) to nearest 1/128"
   b) to nearest 0.1 mm
5. Measure plug gauges for taper using vernier micrometer--tabulate findings.
6. Measure depth of hole in recessed shaft. List in table in order of magnitude.
7. Measure aluminum block using appropriate instruments. Complete top and side views. Include all dimensions required for manufacture.



SUMMATION:

1. To how many decimal places can the constructed caliper measure?
2. What geometrical construction was involved in procedure step #1? Why?
3. Of the instruments used, which was: a) the most accurate? b) the most versatile?
4. Check hair thickness of: student A ____; student B ____; student C ____
5. Check nichrome wire thickness.

Station ⬡ AVIATION HIGH SCHOOL Exp.# 11 APPLIED PHYSICS LABORATORY Team ○

> "One of the foundation stones of science is man's faculty for measurement... Some have even said that science *is* measurement."
>
> Edward Condon

PROBLEM: To precisely check the dimensions of a machined plate using plug gauges, a vernier height gauge, and a dial indicator.

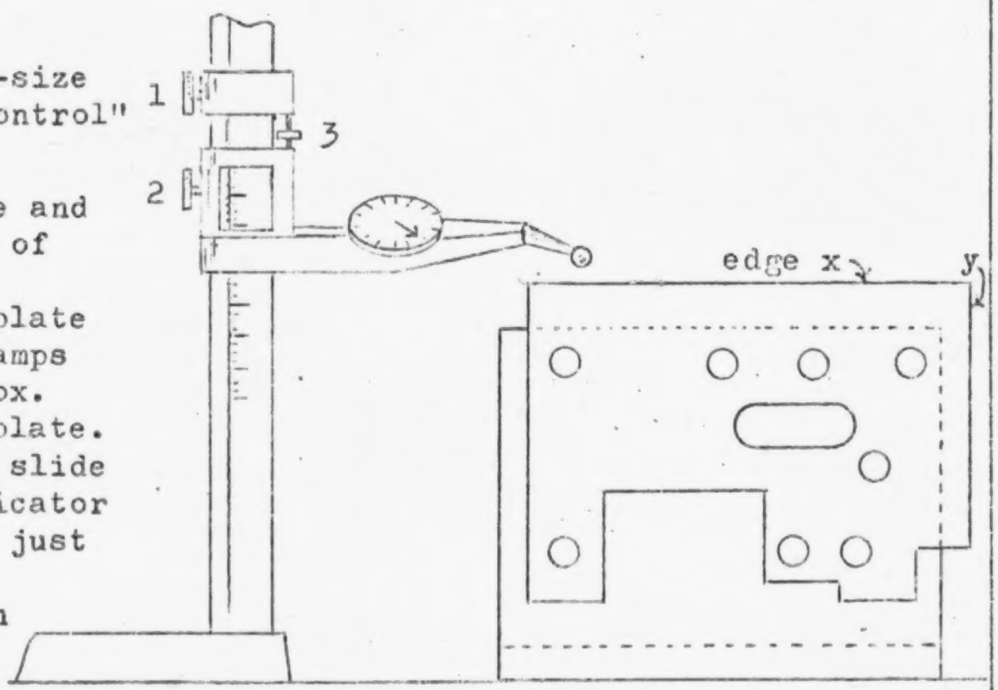
APPARATUS:

Height gauge
Dial indicator
Machined plate
Surface plate
Plastic hammer
2 C clamps
Angle plate
Ruler
Plug gauges

REFERENCES:

GATHERING THE DATA:

1. Make an approximately full-size tracing of the "numerical control" machined plate.



2. a) Thoroughly clean surface and angle plates, and bottom of surface gauge.
   b) Loosely mount machined plate on angle plate with C clamps such that edge x is approx. parallel to the surface plate.
   c) Open screws 1 and 2 and slide vernier scale & dial indicator down until indicator nib just touches edge x.
   d) Tighten screw 1 and turn fine adjustment 3 until needle registers several thousandths--turn indicator dial face to zero and move height gauge so that it indicates parallel edge x.
   --tap with plastic hammer to secure parallel edge.
   --tighten plate in place when edge x parallel to surface plate.
   e) Reset dial face and indicator nib for deflection indicating zero.
   f) Read height gauge and record reading.

   Note: the relative positions of the indicator and vernier slide with respect to each other must not be disturbed during remainder of checking.

   g) Open screw 1 and roughly adjust vernier slide and indicator until indicator nib fits into hole #1.
   h) Tighten screw 1 and fine adjust screw 3 until dial indicator reads zero at bottom of hole #1--move height gauge to assure that bottom of the hole is being checked.
   i) Read and record height gauge reading, subtract from reading in step f.
   --this is the dimension between hole bottom and edge x.
   j) Check hole size with plug gauge and subtract half this measurement (i.e. hole radius) from step i reading--this yields dimension from edge x to the center of hole #1.

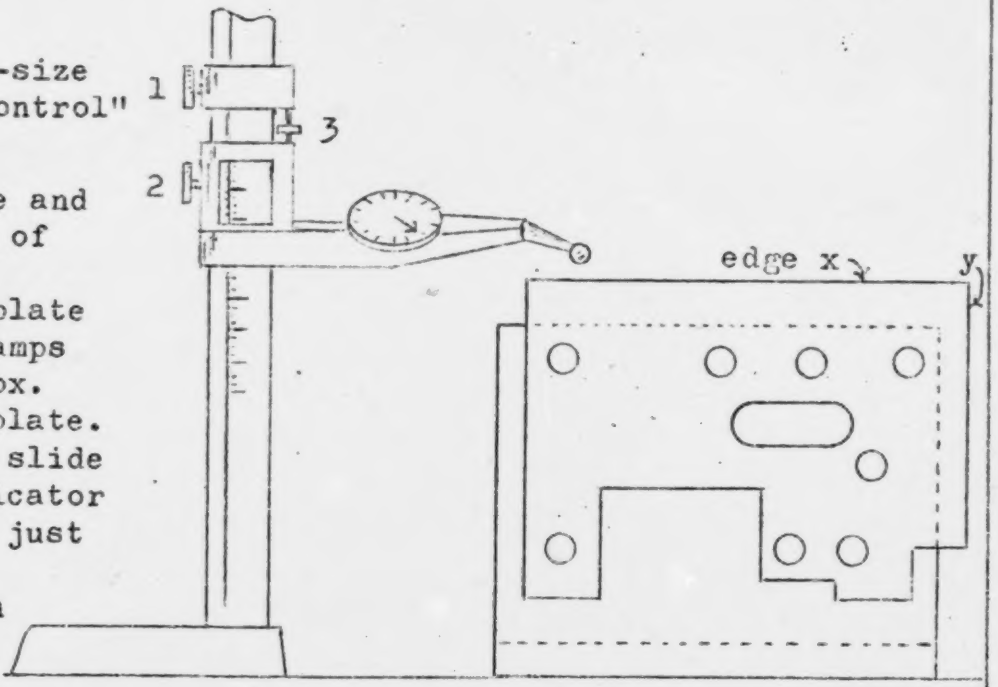
PROBLEM: To precisely check the dimensions of a machined plate using plug gauges, a vernier height gauge, and a dial indicator.

APPARATUS:

- Height gauge
- Dial indicator
- Machined plate
- Surface plate
- Plastic hammer
- 2 C clamps
- Angle plate
- Ruler
- Plug gauges

REFERENCES:

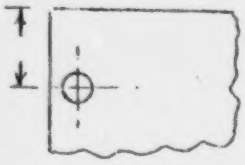
GATHERING THE DATA:



1. Make an approximately full-size tracing of the "numerical control" machined plate.
2. a) Thoroughly clean surface and angle plates, and bottom of surface gauge.
   b) Loosely mount machined plate on angle plate with C clamps such that edge x is approx. parallel to the surface plate.
   c) Open screws 1 and 2 and slide vernier scale & dial indicator down until indicator nib just touches edge x.
   d) Tighten screw 1 and turn fine adjustment 3 until needle registers several thousandths--turn indicator dial face to zero and move height gauge so that it indicates parallel edge x.
   --tap with plastic hammer to secure parallel edge.
   --tighten plate in place when edge x parallel to surface plate.
   e) Reset dial face and indicator nib for deflection indicating zero.
   f) Read height gauge and record reading.

   Note: the relative positions of the indicator and vernier slide with respect to each other must not be disturbed during remainder of checking.

   g) Open screw 1 and roughly adjust vernier slide and indicator until indicator nib fits into hole #1.
   h) Tighten screw 1 and fine adjust screw 3 until dial indicator reads zero at bottom of hole #1--move height gauge to assure that bottom of the hole is being checked.
   i) Read and record height gauge reading, subtract from reading in step f.
   --this is the dimension between hole bottom and edge x.
   j) Check hole size with plug gauge and subtract half this measurement (i.e. hole radius) from step i reading--this yields dimension from edge x to the center of hole #1.
   k) Enter this answer on full size sketch as follows:
   --specify size to closest thousandth of an inch.



3. Repeat step #2 for holes 2, 3, 4, 5, 6, 7, and 8.
4. Turn angle plate so that edge y is parallel to surface plate and repeat steps #2, and #3 for holes 1,2,3,4,5,6,7, and 8.

SUMMATION:

1. Devise a method for checking step dimensions. Explain.
   Implement method and record dimensions on full-size sketch.
2. Devise a method for checking slot width and determining the center locations of the slot's end radii. Explain.
   Implement method and record dimensions on full-size sketch.

Station

AVIATION HIGH SCHOOL

Exp.# 12

APPLIED PHYSICS LABORATORY

Team

> "Audiences love simple experiments and, strangely enough, it is often the advanced scientist who is most delighted by them."
>
> Lawrence Bragg

PROBLEM: To experimentally determine the length of a molecule.

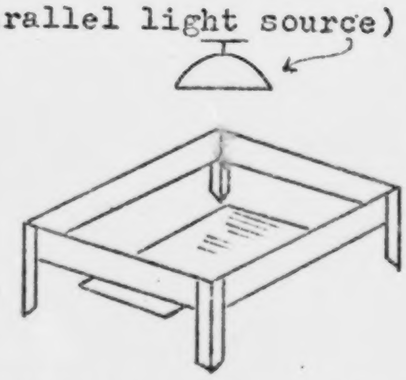
APPARATUS:

- Medicine dropper
- 25ml grad. cylinder
- Table power leads
- Parabolic light source
- 0.5% oleic acid solution
- Lycopodium powder & shaker
- Ripple tank
- 12v. DC
- Graph paper
- 1000ml beaker
- Level

REFERENCES:

1. Rogers, Physics for the Inquiring Mind, pp. 100-3
2. PSSC, Physics, pp. 141-3
3. PSSC, Lab. Guide Physics, p. 10
4. Taffel, Lab. Manual, pp. 91-93

GATHERING THE DATA:



1. Level ripple tank. Parallel light source above its center.
2. Determine the volume of 1 drop of oleic acid solution. (Use water)
   --place many drops in the graduated cyl., accurately measure total volume and count number of drops.
   --calculate volume for 1 drop.
3. From solution specifications, determine the actual volume of oleic acid in a drop of the solution.
4. a) Fill ripple tank with clean water to a depth of approximately 1 cm.
   b) Gently dust the water surface with lycopodium powder, and place one drop of oleic acid at the center of the ripple tank--wait for the oleic acid film to form a stable configuration.
   (Practice placing drops before actually putting one in the ripple tank.)
   c) Place graph paper beneath the ripple tank and carefully trace the oleic acid film shape.
   d) Determine the area of the film by counting squares. Convert area to square centimeters.
   e) Clean ripple tank using detergent and alcohol. Do not let grease or foreign matter enter it, and repeat the above steps a through d to check consistency of results.
5. Using oleic acid volume, not oleic acid solution volume, determine average thickness of film.

Drops	Acid Vol. cm^3 = V	Film Area cm^2 = A	Film Thickness = V/A

6. After completing summation, clean ripple tank and repeat steps #4 and #5 for 2 and then 3 acid solution drops.

SUMMATION:

1. Describe the properties of oleic acid with respect to alcohol and to water

PROBLEM: To experimentally determine the length of a molecule.

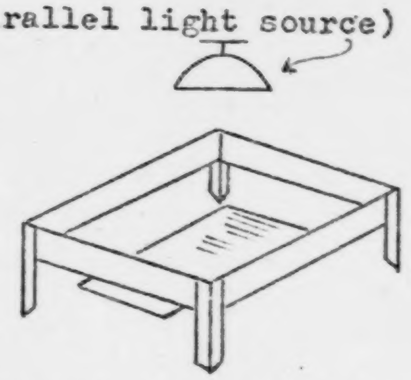
APPARATUS:

Medicine dropper
25ml grad. cylinder
Table power leads
Parabolic light source
0.5% oleic acid solution
Lycopodium powder & shaker
Ripple tank
12v. DC
Graph paper
1000ml beaker
Level

REFERENCES:

1. Rogers, Physics for the Inquiring Mind, pp. 100-3
2. PSSC, Physics, pp. 141-3
3. PSSC, Lab. Guide Physics, p. 10
4. Taffel, Lab. Manual, pp. 91-93

GATHERING THE DATA:



1. Level ripple tank. Parallel light source above its center.
2. Determine the volume of 1 drop of oleic acid solution. (Use water)
   --place many drops in the graduated cyl., accurately measure total volume and count number of drops.
   --calculate volume for 1 drop.
3. From solution specifications, determine the actual volume of oleic acid in a drop of the solution.
4. a) Fill ripple tank with clean water to a depth of approximately 1 cm.
   b) Gently dust the water surface with lycopodium powder, and place one drop of oleic acid at the center of the ripple tank--wait for the oleic acid film to form a stable configuration.
   (Practice placing drops before actually putting one in the ripple tank.)
   c) Place graph paper beneath the ripple tank and carefully trace the oleic acid film shape.
   d) Determine the area of the film by counting squares. Convert area to square centimeters.
   e) Clean ripple tank using detergent and alcohol. Do not let grease or foreign matter enter it, and repeat the above steps a through d to check consistency of results.
5. Using oleic acid volume, not oleic acid solution volume, determine average thickness of film.

Drops	Acid Vol. cm^3 = V	Film Area cm^2 = A	Film Thickness = V/A

6. After completing summation, clean ripple tank and repeat steps #4 and #5 for 2 and then 3 acid solution drops.

SUMMATION:

1. Describe the properties of oleic acid with respect to alcohol and to water that make it especially appropriate for use in this experiment.
2. Assuming that an oleic acid molecule has a cubical shape and that the oleic acid film consists of a single layer of tightly bunched molecules, what is the length of an oleic acid molecule?
3. If the density of oleic acid = 0.895 $\frac{gm}{cm^3}$. Calculate mass of one molecule.
4. If a mole of oleic acid has a mass of 282gm, then:
   a) according to experimental data, how many molecules are in a mole of acid?
   b) how closely does answer a agree with Avogadro's number?
   c) explain discrepancy--if any.
5. What is the actual shape of the oleic acid molecule?
   How does it position itself in water?
   How does this affect accuracy of answers?
6. What evidence is available regarding molecule thickness of oleic acid film?

Station　　　　Exp. #　　　　Team

AVIATION HIGH SCHOOL　　13　　APPLIED PHYSICS LABORATORY

> "To appreciate the living spirit rather than the dry bones of mathematics it is necessary to inspect the work of a master at first hand ... The very crudities of the first attack on a significant problem by a master are more illuminating than all the pretty elegance of the standard texts which have been won at the cost of perhaps centuries of finicky polishing."
>
> E. T. Bell

PROBLEM: To experimentally determine constants of proportionality.

APPARATUS:

Meter stick	1/10" graph paper
Rods	Parabolic light
Surface gauge	Table leads & 12v DC
Tapered cup	Vernier caliper
Support ring	Protractor & arm
Table bars	10 ml cylinder
Med. dropper	Disc
2 iron bases & rods	

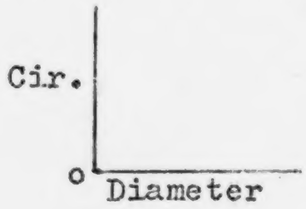
REFERENCES:

1. Rogers, Physics for the Inquiring Mind, pp. 199-202
2. Handbook of Chemistry & Physics,
3. Kline, Mathematics in Western Culture, pp. 49-51

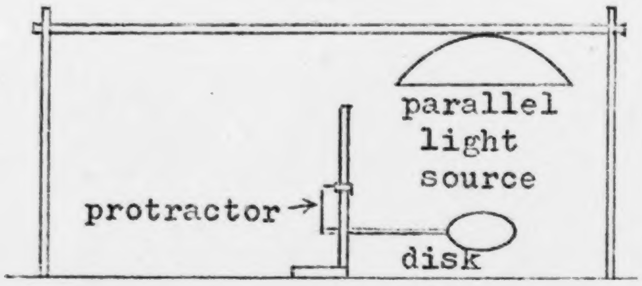
GATHERING THE DATA:

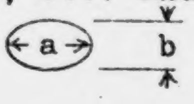
1. a) Measure circumferences of rods by tightly wrapping thread 10 times about each. (Use knot to indicate start of thread.)
   b) Measure rod diameters with vernier caliper.
   c) List results in table and calculate circumference.
   d) Plot graph:

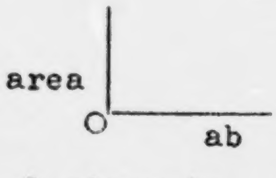
Rod	Dia. (mm)	10 x Cir. (mm)	Circumference
A			
B			
etc.			



2. a) Position disk parallel and close to table top (disk should cast full-size circular shadow).
   b) Trace shadow on graph paper and approximate area.
   c) Connect protractor and pointer to permit measured tilting of disk through 80°.
   d) Successively tilt 10°, 20°, etc. and measure shadow's a and b list in table.
   e) Plot graph:

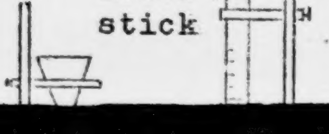






Degree Tilt	Area	a	b	ab
0°				
10°				
80°				

3. a) Add water in 2 ml steps to tapered cup.
   b) Measure corresponding



ml	Water depth (mm)
2	

> pretty elegance of the standard texts which have been won at the cost of perhaps centuries of finicky polishing."
>
> E. T. Bell

PROBLEM: To experimentally determine constants of proportionality.

APPARATUS:

Meter stick	1/10" graph paper
Rods	Parabolic light
Surface gauge	Table leads & 12v DC
Tapered cup	Vernier caliper
Support ring	Protractor & arm
Table bars	10 ml cylinder
Med. dropper	Disc
2 iron bases & rods	

REFERENCES:

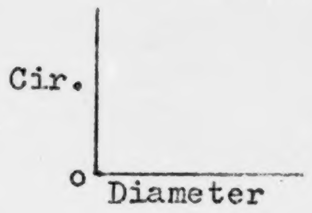
1. Rogers, Physics for the Inquiring Mind, pp. 199-202
2. Handbook of Chemistry & Physics,
3. Kline, Mathematics in Western Culture, pp. 49-51

GATHERING THE DATA:

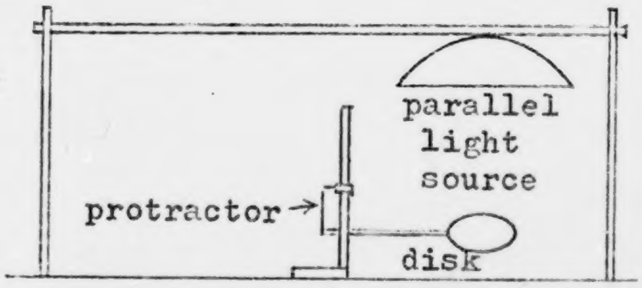
1. a) Measure circumferences of rods by tightly wrapping thread 10 times about each. (Use knot to indicate start of thread.)
   b) Measure rod diameters with vernier caliper.
   c) List results in table and calculate circumference.

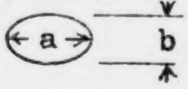
Rod	Dia. (mm)	10 x Cir. (mm)	Circumference
A			
B			
etc.			

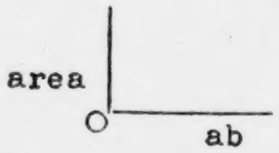
   d) Plot graph:



2. a) Position disk parallel and close to table top (disk should cast full-size circular shadow).
   b) Trace shadow on graph paper and approximate area.
   c) Connect protractor and pointer to permit measured tilting of disk through 80°.
   d) Successively tilt 10°, 20°, etc. and measure shadow's a and b list in table.
   e) Plot graph:

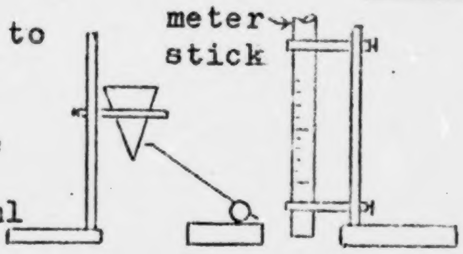






Degree Tilt	Area	a	b	ab
0°				
10°				
80°				

3. a) Add water in 2 ml steps to tapered cup.
   b) Measure corresponding water depth using surface gauge.
   c) Plot graph: depth vs. ml



ml	Water depth (mm)
2	
4	
etc.	

SUMMATION:

1. a) What kind of relationship is revealed by the graph in step #1 above?
   b) According to experimental data, what is the value of the constant of proportionality? What symbol represents this constant?
   c) What advantage does graph have over table in presenting proportionality?
2. a) What kind of relationship exists between the product ab and the shadow's area? What kind of geometric shape is involved?
   b) What constant of proportionality relates ab and area? ab/4 and area?
   c) How closely does experimental finding agree with that listed in mathematics books?
   d) Calculate area of an ellipse made by the "string method". Check by graph paper method.
3. According to experimental data, what kind of relationship, if any, exists between the volume of a cone and its height?

Station

AVIATION HIGH SCHOOL Exp.# 14 **APPLIED PHYSICS LABORATORY**

Team

> "Physics is an experimental science.... Experiment is the court of highest appeals in all physical results predicted by mathematical analysis. To attempt, therefore, to teach sound physics and good scientific method without laboratory work on the part of the student is to attempt the impossible."
>
> Henry Crew

PROBLEM: To experimentally determine the factors in pendulum period. (Part I)

APPARATUS:

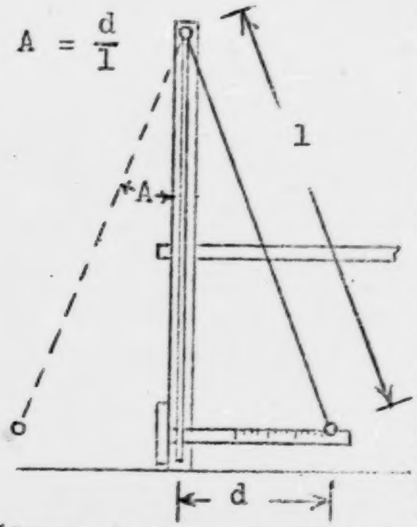
- Pendulum support
- Assorted bobs
- Square & meter stick
- Pendulum arm
- Stop-watch
- Meter tape
- Cord

REFERENCES:

1. Beiser, The Science of Physics, pp. 174-6
2. Beiser, Basic Concepts of Physics, pp. 97-9
3. White, Modern College Physics, pp. 248-50

GATHERING THE DATA:

Sin A = $\frac{d}{l}$



(keep bob near floor -- Watch Toes!)

1. Investigate the relation of pendulum period to amplitude for various starting amplitudes.
   a) attach pendulum arm approx. 1m above floor
   b) thread cord through brass bob & arm and carefully measure desired pendulum length.
   c) displace bob through amplitude angle A = 5° --determined trigonometrically
   d) carefully release bob after all vibration has ceased.
   e) call zero when releasing bob, one when it returns to starting position, etc.
   f) check period for 5°, 10°, 15°, 20°, 25°, 30°, 40°, 50°, 60°, 70°, 80°, and 90°. -- time 20 cycles for each (use average of 3 trials for each).
   g) record data in table:

Amplitude Angle	Pendulum Length	t (sec) 20 cycles	Period = t/cycles
5°	1m		
10°	1m		
80°	1m		
90°	1m		

2. Investigate the consistency of period for a 10° starting amplitude.
   --Time for 10, 20, 30, etc. cycles

the part of the student is to attempt the impossible."

Henry Crew

PROBLEM: To experimentally determine the factors in pendulum period. (Part I)

APPARATUS:

Pendulum support	Stop-watch
Assorted bobs	Meter tape
Square & meter stick	Cord
Pendulum arm	

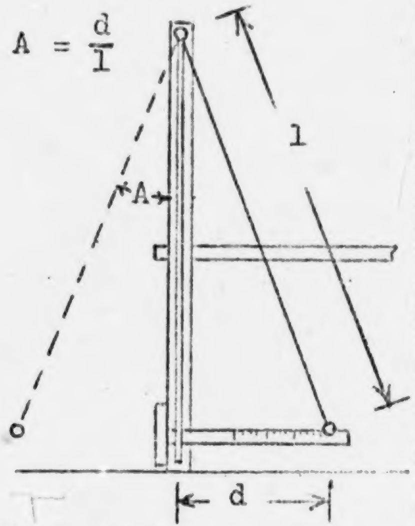
REFERENCES:

1. Beiser, The Science of Physics, pp. 174-6
2. Beiser, Basic Concepts of Physics, pp. 97-9
3. White, Modern College Physics, pp. 248-50

GATHERING THE DATA:

1. Investigate the relation of pendulum period to amplitude for various starting amplitudes.
   a) attach pendulum arm approx. 1m above floor
   b) thread cord through brass bob & arm and carefully measure desired pendulum length.
   c) displace bob through amplitude angle A = 5° --determined trigonometrically
   d) carefully release bob after all vibration has ceased.
   e) call zero when releasing bob, one when it returns to starting position, etc.
   f) check period for 5°, 10°, 15°, 20°, 25°, 30°, 40°, 50°, 60°, 70°, 80°, and 90°.
      -- time 20 cycles for each (use average of 3 trials for each).
   g) record data in table:

$\text{Sin } A = \frac{d}{l}$



(keep bob near floor -- Watch Toes!)

Amplitude Angle	Pendulum Length	t (sec) 20 cycles	Period = t/cycles
5°	1m		
10°	1m		
80°	1m		
90°	1m		

2. Investigate the consistency of period for a 10° starting amplitude.
   --Time for 10, 20, 30, etc. cycles
   --Do not interrupt trial until all readings have been taken

# of cycles	Pendulum length	t(trial #1)	t (trial #2)	t (trial #3)	Period
10	1m				
20	1m				
etc.	1m				

3. Investigate the relation of period to bob mass:

Bob	Amp. Angle	Pendulum Length	t for 20 cycles	Period
brass	10°	1.5m		
iron	10°	1.5m		
aluminum	10°	1.5m		
wood	10°	1.5m		

Station ⬡

AVIATION HIGH SCHOOL

Exp.# 15

APPLIED PHYSICS LABORATORY

Team ○

"In this matter of authorship, the important thing is to get the facts. First get the facts; and then you can distort them at your leisure."

Mark Twain

"Since there are no--or only a very few--ideal people, who are entirely free from prejudice, it is sometimes of value to obtain information, especially in regard to historical data, from two different points of view."

Wilhelm K. Röntgen

PROBLEM: To experimentally determine the factors in pendulum period and to examine the Foucault pendulum. (Part II)

APPARATUS:

1" dia. brass bob
Square & meter stick
Meter tape measure
Foucault apparatus
Pendulum support & arm
Model Foucault apparatus
Stop-watch
Phonograph
Graph paper
Cord

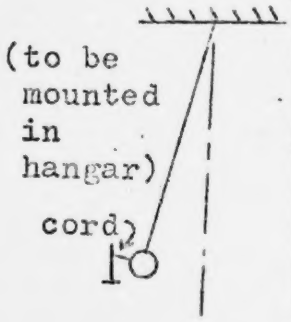
REFERENCES:

1. Beiser, Basic Concepts of Physics, pp. 97-9
2. White, Modern College Physics, pp. 248-50
3. Kittel, Berkeley Physics Course I, pp. 77-9

GATHERING THE DATA:

1. a) Release Foucault pendulum by burning cord holding it off center.
   b) Confirm that pendulum swings in direction indicated by white tape on deck.
   c) Check pendulum angular motion with respect to white tape at 5 or 10 minute intervals.

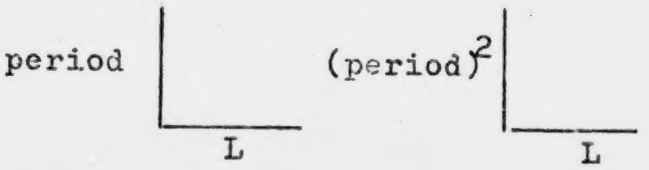
Important
Do not touch Foucault Pendulum until ready for experiment.



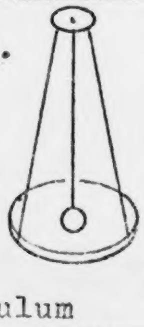
2. Set up pendulum as in part I and check relation of period to pendulum length (use brass bob, 10° starting amplitude & indicated lengths--time each for 50 cycles).

Pendulum length	Material	Amplitude Angle	Time 50 cycles	Period
2.5 m	brass	10°		
2.25m	brass	10°		
0.5 m	brass	10°		

3. Plot graphs:



4. Place Foucault Model on phonograph.
   --level phonograph so that bob points to center.
   --move bob off center to one of the supports.
   --release bob & permit table to turn at 16 RPM.
   --observe relation of table to pendulum



SUMMATION: (Parts I and II)

"Since there are no--or only a very few--ideal people, who are entirely free from prejudice, it is sometimes of value to obtain information, especially in regard to historical data, from two different points of view."

Wilhelm K. Röntgen

PROBLEM: To experimentally determine the factors in pendulum period and to examine the Foucault pendulum. (Part II)

APPARATUS:

- 1" dia. brass bob
- Square & meter stick
- Meter tape measure
- Foucault apparatus
- Pendulum support & arm
- Model Foucault apparatus
- Stop-watch
- Phonograph
- Graph paper
- Cord

REFERENCES:

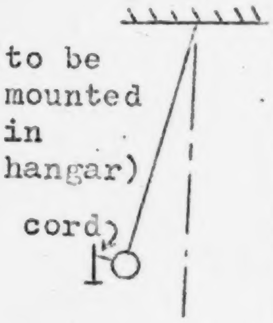
1. Beiser, Basic Concepts of Physics, pp. 97-9
2. White, Modern College Physics, pp. 248-50
3. Kittel, Berkeley Physics Course I, pp. 77-9

GATHERING THE DATA:

1. a) Release Foucault pendulum by burning cord holding it off center.
   b) Confirm that pendulum swings in direction indicated by white tape on deck.
   c) Check pendulum angular motion with respect to white tape at 5 or 10 minute intervals.

Important
Do not touch Foucault Pendulum until ready for experiment.

(to be mounted in hangar)



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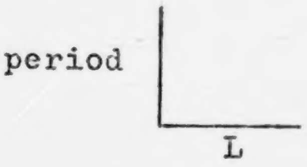
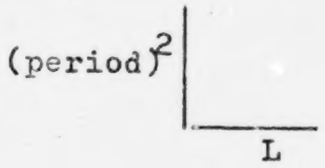
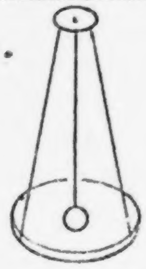
Pendulum length	Material	Amplitude Angle	Time 50 cycles	Period
2.5 m	brass	10°		
2.25m	brass	10°		
0.5 m	brass	10°		

3. Plot graphs:





4. Place Foucault Model on phonograph.
   --level phonograph so that bob points to center.
   --move bob off center to one of the supports.
   --release bob & permit table to turn at 16 RPM.
   --observe relation of table to pendulum plane.



SUMMATION: (Parts I and II)

1. Of the factors investigated, which have an effect upon period?
2. According to experimental data, what necessary restriction must be placed on the swing of a pendulum clock? Why?
3. When period is plotted against pendulum length, what kind of curve results? What kind of curve results when $(\text{period})^2$ is plotted against L? What kind of a relationship between $(\text{period})^2$ and L is suggested?
4. a) Why is the center of gravity of the cork pendulum more difficult to determine than that of an iron pendulum?
   b) Where is the center of gravity of the cork pendulum? Show calculations.
5. Using the evidence of step #2 in "Gathering the Data" Part II, how long should the brass pendulum be for a one second period? Show calculations.
6. Did the plane of the Foucault pendulum change?
   If so, in which direction--looking down from above?
   According to experimental results, how long would it take the pendulum to move through 360° ?
   How does this agree with data for U.N.'s Foucault pendulum?
7. How does Foucault pendulum illustrate earth's rotation? Foucault vs. Galileo?

Station

Exp.# 16

AVIATION HIGH SCHOOL — APPLIED PHYSICS LABORATORY

Team

> "It took the human race a thousand years to bridge the gulf between the rule of Archimedes and the next stage in the evolution of the logarithmic table. You need not be discouraged if it takes you a few hours or days..."
>
> Lancelot Hogben
>
> "(Henry Briggs) ... published ... in his Arithmetrica Logarithmica (1624)...the logarithms of 30,000 natural numbers to 14 (decimal) places."
>
> Encyclopaedia Britannica

PROBLEM: To construct a slide rule.

APPARATUS:

2 meter sticks
2-3/8"x1 meter paper
Try square
Tape

REFERENCES:

1. Courant, What is Mathematics?, pp. 448-53

REVIEW:

1. Add

$$\begin{array}{r} 253 \\ +431 \\ \hline 684 \end{array} \text{ (1 operation)}$$

Multiply

$$\begin{array}{r} 253 \\ \times 431 \\ \hline 253 \\ 759 \\ 1012 \\ \hline 109043 \end{array} \text{ (4 operations)}$$

i.e. Adding requires less work than multiplying & for bigger numbers the discrepancy between the work required becomes even greater.

2. a) Consider the geometric series -- 2 4 8 16 32 64 128...(antilogs)
which can be written in powers--- 2^1 2^2 2^3 2^4 2^5 2^6 2^7...
& associated with arith. series-- 1 2 3 4 5 6 7 ...(called logs)

b) $\underset{\text{base}}{\xrightarrow{}}2^{3}\xleftarrow{}\underset{\text{log}}{} = 8 \xleftarrow{} \underset{\text{antilog}}{}$ is usually written as $\log_2 8 = 3$
& read as "the log of 8 to the base 2 = 3"

3. According to the Principle of Archimedes, to multiply any two numbers--say 8x16--add their logs and this new log is the log of the answer:

logs reduce multiplication to addition

$2^3 \times 2^4 = 2^7 = 128$ or $\log 8 = 3$
$\log 16 = 4$
$\log (8\times16) = \overline{7} \rightarrow 8\times16 = 128$

logs reduce division to subtraction

$\frac{64}{16} \rightarrow \frac{2^6}{2^4} = 2^2 = 4$ or $\log 64 = 6$
$\log 16 = 4$
$64/16=4 \longleftarrow \log (64/16) = \overline{2}$

PROCEDURE: 1. Determine several logs to base 10 by rough approx. as follows:

a) $1=10^0 \rightarrow \log_{10} 1 = 0$ since $\frac{10^1}{10^1} = 10^0$

b) $2^{10} = 1{,}024$
$2^{10} \doteq 10^3 \rightarrow 2 \doteq \sqrt[10]{10^3} = 10^{3/10} = 10^{.3} \rightarrow \log_{10} 2 \doteq .3$

c) $3^9 = 19{,}681$
$3^9 \doteq 20{,}000 = 2\times10^4 = 10^{.3}\times10^4 = 10^{4.3} \rightarrow \log_{10} 3 \doteq .48$

d) $\log_{10} 4 \doteq 0.6$ from $4=2^2 = 10^{0.3}\times10^{0.3}$

e) $\log_{10} 5$.

f) $\log_{10} 6 \doteq 0.78$ from $6=2\times3$

g) $\log_{10} 7 \doteq 0.85$ from:
$7\times7 \doteq 5\times10$

h) $\log_{10} 8 \doteq 0.90$ from $8=2^3$

i) $\log_{10} 9 \doteq 0.96$ from $9=3^2$

> ... published ... in his Arithmetica Logarithmica (1624)...the logarithms of 30,000 natural numbers to 14 (decimal) places."
>
> Encyclopaedia Britannica

PROBLEM: To construct a slide rule.

APPARATUS:

2 meter sticks
2-3/8"x1 meter paper
Try square
Tape

REFERENCES:

1. Courant, What is Mathematics?, pp. 448-53

REVIEW:

1. Add

$$\begin{array}{r} 253 \\ +431 \\ \hline 684 \end{array}$$

(1 operation)

Multiply

$$\begin{array}{r} 253 \\ \times 431 \\ \hline 253 \\ 759 \\ 1012 \\ \hline 109043 \end{array}$$

(4 operations)

i.e. Adding requires less work than multiplying & for bigger numbers the discrepancy between the work required becomes even greater.

2. a) Consider the geometric series -- 2 4 8 16 32 64 128...(antilogs)
which can be written in powers--- 2^1 2^2 2^3 2^4 2^5 2^6 2^7...
& associated with arith. series-- 1 2 3 4 5 6 7 ...(called logs)

b) $\underset{\text{base}}{2}\!\overset{3}{}\ \text{log} = \underset{\text{antilog}}{8}$ is usually written as $\log_2 8 = 3$
& read as "the log of 8 to the base 2 = 3"

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logs reduce multiplication to addition

$2^3 \times 2^4 = 2^7 = 128$ or $\log 8 = 3$
$\log 16 = 4$
$\log(8\times16) = \overline{7} \rightarrow 8\times16 = 128$

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$\log 16 = 4$
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PROCEDURE: 1. Determine several logs to base 10 by rough approx. as follows:

a) $1=10^0 \rightarrow \log_{10}1=0$ since $\frac{10^1}{10^1} = 10^0$

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$2^{10} \doteq 10^3 \rightarrow 2 \doteq \sqrt[10]{10^3} = 10^{3/10} = 10^{.3} \rightarrow \log_{10}2 \doteq .3$

c) $3^9 = 19{,}681$
$3^9 \doteq 20{,}000 = 2\times10^4 = 10^{.3}\times10^4 = 10^{4.3} \rightarrow \log_{10}3 \doteq .48$

d) $\log_{10}4 \doteq 0.6$ from $4=2^2=10^{0.3}\times10^{0.3}$

e) $\log_{10}5 \doteq 0.7$ from $2\times5 = 10$

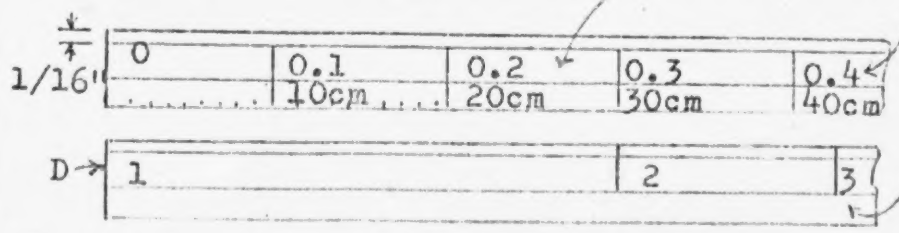
f) $\log_{10}6 \doteq 0.78$ from $6=2\times3$

g) $\log_{10}7 \doteq 0.85$ from: $7\times7 \doteq 5\times10$

h) $\log_{10}8 \doteq 0.90$ from $8=2^3$

i) $\log_{10}9 \doteq 0.96$ from $9=3^2$

2. Construct a slide rule.

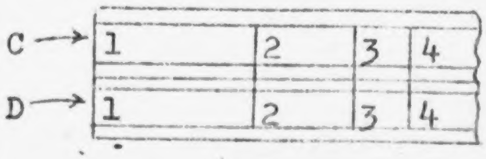


a) Tape white paper to meter stick.

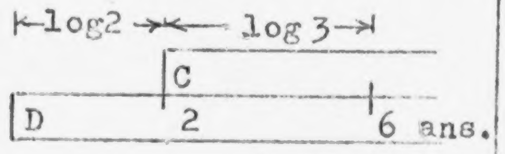
b) Lightly renumber in pencil so that 10 cm = 0.1
20 cm = 0.2
100 cm = 1.0

c) Using original accurate divisions on meter stick, locate logs & label in ink with antilog values.

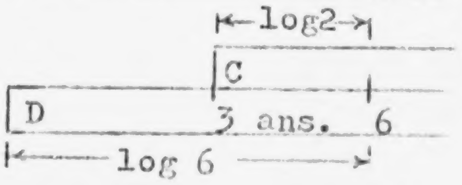
3. Construct duplicate scale (by matching)



4. Mult. 2 x 3 by adding logs.



5. Divide 6 ÷ 2 by subtracting logs.



SUMMATION:

Solve: 2 x 2; 4 x 2; 5 x 2; $\frac{8}{2}$; $\frac{10}{5}$; $\frac{8}{4}$; $\frac{6}{3}$; $\frac{4}{2}$; $\frac{2}{4}$; $\frac{4}{5}$; $\frac{3}{5}$; (Explain discrepancies)

Station ⬡ **AVIATION HIGH SCHOOL** Exp.# 17 **APPLIED PHYSICS LABORATORY** Team ○

> "Obvious is the most dangerous word in mathematics." E. T. Bell
>
> "Young authors...always over estimate the capacity of their audience to grasp at short notice and in quick time ideas which they themselves have slowly and painfully evolved."
> J. J. Thomson

PROBLEM: To perform calculations using a slide rule.

APPARATUS:

Triangles Polygon
Circles
3-Mannheim type slide rules

REFERENCES:

1. Acu-Math, Instruction Manual

PROCEDURE:

1. Locate the following numbers on the D scale: 1.4; 1.9; 2.1; 3.2; 3.6; 4.4; 8.9; 1.25; 1.46; 2.15; 3.05; and 1.02. (Check work against instruction sheet).

2. What other scale on the slide rule is an exact duplicate of scale D?

3. Multiply 2 x 2 and check against instruction sheet.
   Multiply a) 12 x 12 d) 1.4 x 5 g) 13.5 x 15 x 4
   b) 24 x 30 e) 16.2 x 34 h) 85 x 6 x 4.5
   c) 25 x 25 f) 32 x 19 i) 108 x 31.5 x 50.5

4. Divide: 5 ÷ 4 and check against instruction sheet.
   Divide a) 625 ÷ 25 b) 550 ÷ 32 c) 34 ÷ 675 d) 24.4 ÷ 3.64

5. Use the CI and D scales to get the decimal equivalents of the following:
   $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{3}{16}$, $\frac{3}{25}$, $\frac{3}{12}$, $\frac{5}{18}$, $\frac{5}{16}$, $\frac{7}{32}$, $\frac{7}{64}$, $\frac{9}{64}$, $\frac{9}{32}$

6. Get the squares of the following numbers using the D and A scales:
   5 (see inst. sheet), 26, 19, 55, 25, 13

7. Extract square roots using the A and D scales:
   2500 (see inst. sheet); 250 (see inst. sheet); 289; 4096

8. Extract cube roots using D and K scales:
   27 (see inst. sheet); 1250 (see inst. sheet); 216; 1728

9. Determine the logs of numbers using D and L scales:
   4 (see inst. sheet); 15; 27; 78; e = 2.718

10. Determine the sines of the following angles using the S and A scales:
    $15^\circ 48'$ (see inst. sheet); $1^\circ 20'$ (see inst.sheet); 30°; 15°; 5°

11. Determine the tangents of the following angles using the D and T scales:
    $6^\circ 45'$ (see inst. sheet); 30°; 10°; $7^\circ 30'$

12. 1" = 2.54 cm -- match these quantities on the C & D scales and make the following conversions: a) to inches: 65cm; 110cm; 865cm
    b) to cm : 4" ; 45" ; 9.6"; 756"

13. Calculate the areas of circles A, B, and C.

PROBLEM: To perform calculations using a slide rule.

APPARATUS:

Triangles Polygon
Circles
3-Mannheim type slide rules

REFERENCES:

1. Acu-Math, Instruction Manual

PROCEDURE:

1. Locate the following numbers on the D scale: 1.4; 1.9; 2.1; 3.2; 3.6; 4.4; 8.9; 1.25; 1.46; 2.15; 3.05; and 1.02. (Check work against instruction sheet).

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4. Divide: 5 ÷ 4 and check against instruction sheet.
   Divide a) 625 ÷ 25 b) 550 ÷ 32 c) 34 ÷ 675 d) 24.4 ÷ 3.64

5. Use the C_1 and D scales to get the decimal equivalents of the following:
   $\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{16}, \frac{3}{16}, \frac{3}{25}, \frac{3}{12}, \frac{5}{18}, \frac{5}{16}, \frac{7}{32}, \frac{7}{64}, \frac{9}{64}, \frac{9}{32}$

6. Get the squares of the following numbers using the D and A scales:
   5 (see inst. sheet), 26, 19, 55, 25, 13

7. Extract square roots using the A and D scales:
   2500 (see inst. sheet); 250 (see inst. sheet); 289; 4096

8. Extract cube roots using D and K scales:
   27 (see inst. sheet); 1250 (see inst. sheet); 216; 1728

9. Determine the logs of numbers using D and L scales:
   4 (see inst. sheet); 15; 27; 78; e = 2.718

10. Determine the sines of the following angles using the S and A scales:
   15° 48' (see inst. sheet); 1° 20' (see inst.sheet); 30°; 15°; 5°

11. Determine the tangents of the following angles using the D and T scales:
   6° 45' (see inst. sheet); 30°; 10°; 7° 30'

12. 1" = 2.54 cm -- match these quantities on the C & D scales and make the following conversions: a) to inches: 65cm; 110cm; 865cm
   b) to cm : 4"; 45"; 9.6"; 756"

13. Calculate the areas of circles A, B, and C.
   use $\frac{\pi d^2}{4}$ instead of πr^2 (since $\frac{\pi}{4}$ = .785, why is the first equation a time saver)

14. Extract roots using logs:
   ex. $\sqrt[3]{27}$: $\log \sqrt[3]{27} = \frac{1}{3} \log 27 = \frac{1}{3} \overset{\text{via L scale}}{(1.4315)} = 0.477$ & $\sqrt[3]{27} = 3$ (D scale)
   $\sqrt[5]{248,832}$ $\sqrt[12]{1,594,323}$ $\sqrt[7]{16,384}$

15. Measure the sides of triangles P, Q, and R, and determine the missing angles using the law of sines.

16. Determine the angles of the polygon by measuring the sides and applying the law of cosines. (Note: $\cos \phi = \sin (90 - \phi)$)

SUMMATION:

Check results against those of other team members.
Resolve difficulties!

Station

AVIATION HIGH SCHOOL

Exp.# 18

APPLIED PHYSICS LABORATORY

Team

> "Galileo...his fame is usually associated with things--the observation of the isochronisms of the pendulum, or his fight with clericalism over the Copernican theory... It is his establishment of the first experimental numerical law that constitutes his highest claim to greatness..."
>
> Norman Campbell

PROBLEM: To experimentally determine the relationship between the factors involved in the acceleration of gravity.

APPARATUS:

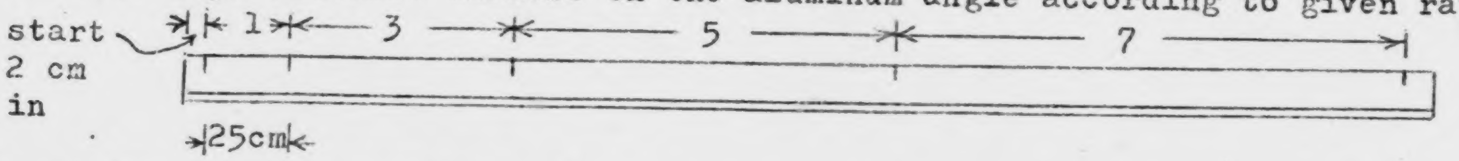
Stop watch	15 meter tape
1" steel ball	Meter stick
Tape	Graph paper
Metronome	Square
Aluminum angle & cord	

REFERENCES:

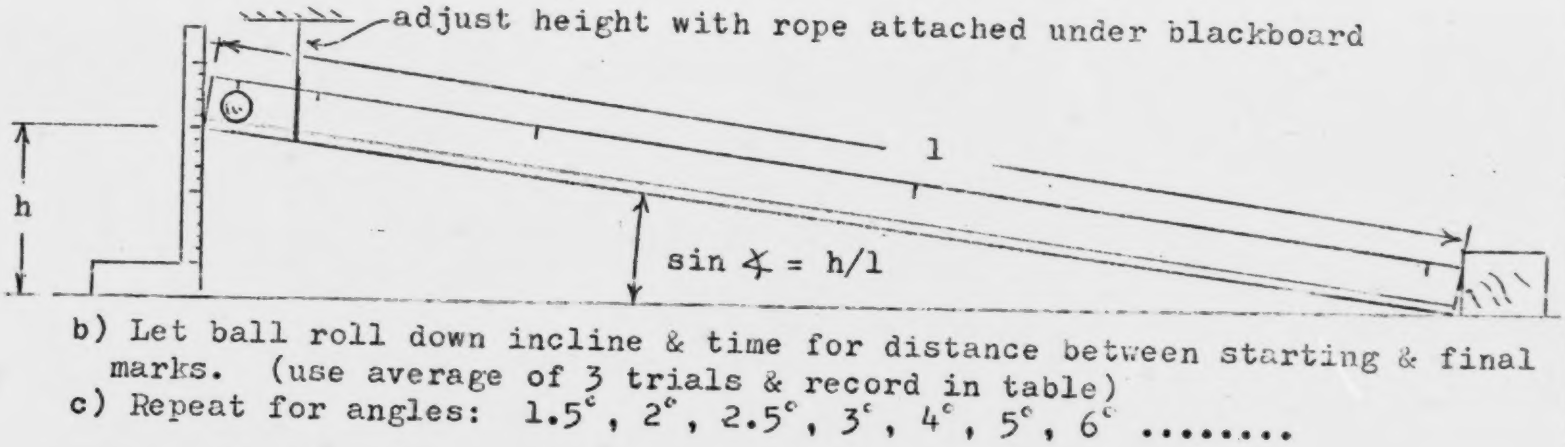
1. Holton, Foundations of Mod. Physical Science, pp. 25-32
2. Halliday & Resnick, Physics, pp. 39-41
3. Rogers, Physics for the Inquiring Mind, p. 115 note #15

GATHERING THE DATA:

1. Place tape distance markers on the aluminum angle according to given ratio:



2. a) Set aluminum angle at 1° angle using trigonometry.



b) Let ball roll down incline & time for distance between starting & final marks. (use average of 3 trials & record in table)

c) Repeat for angles: 1.5°, 2°, 2.5°, 3°, 4°, 5°, 6° ....

Angle	h	l	h/l	Av.total time t	Acceleration a
1					
1.5					
etc.					

3. Check for uniform acceleration at several representative angles:
   --set metronome for an integral number of beats for time during which ball rolls between starting mark & next mark and then note number of beats between other successive marks as ball continues down incline.

SUMMATION:

claim to greatness..."

Norman Campbell

PROBLEM: To experimentally determine the relationship between the factors involved in the acceleration of gravity.

APPARATUS:

Stop watch
1" steel ball
Tape
Metronome
Aluminum angle & cord
15 meter tape
Meter stick
Graph paper
Square

REFERENCES:

1. Holton, Foundations of Mod. Physical Science, pp. 25-32
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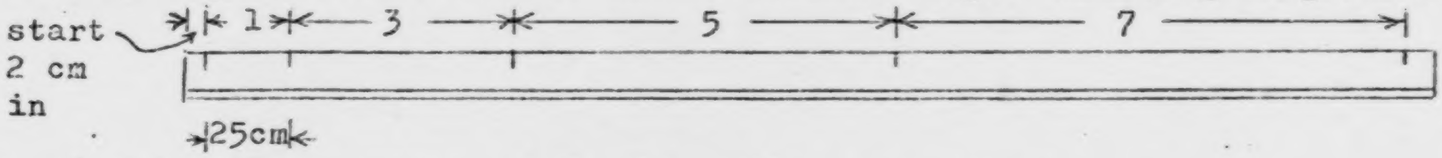
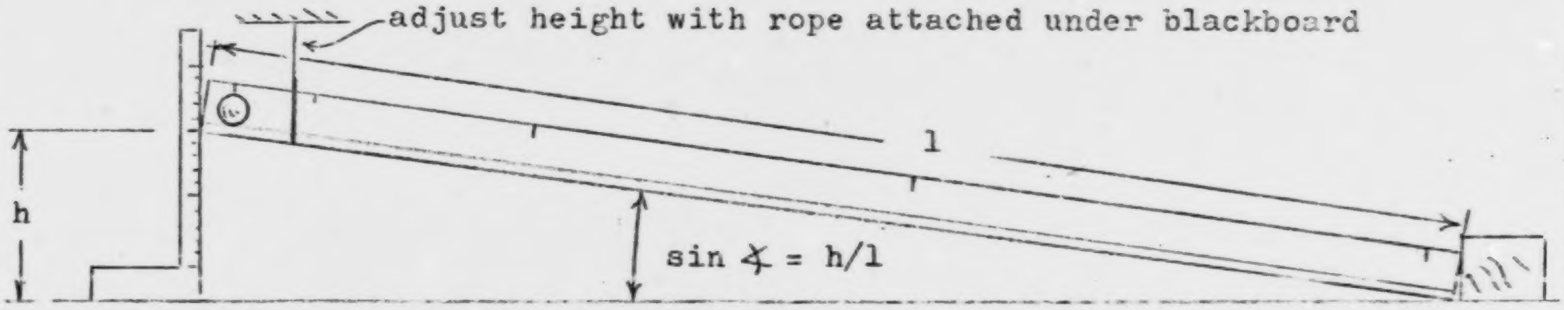
GATHERING THE DATA:

1. Place tape distance markers on the aluminum angle according to given ratio:



2. a) Set aluminum angle at 1° angle using trigonometry.



b) Let ball roll down incline & time for distance between starting & final marks. (use average of 3 trials & record in table)

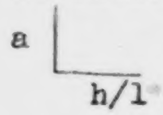
c) Repeat for angles: 1.5°, 2°, 2.5°, 3°, 4°, 5°, 6° ....

Angle	h	l	h/l	Av.total time t	Acceleration a
1					
1.5					
etc.					

3. Check for uniform acceleration at several representative angles:
--set metronome for an integral number of beats for time during which ball rolls between starting mark & next mark and then note number of beats between other successive marks as ball continues down incline.

SUMMATION:

1. How does step #3 of "Gathering the Data" provide evidence that the acceleration for a particular angle is a constant?
2. As angular setting increased, what difficulty was experienced in:
   a) setting the metronome?
   b) timing the ball?
3. Calculate the acceleration for each angular setting using $s = v_i t + \frac{at^2}{2}$.
4. Plot graph:



5. a) If $a \propto \frac{h}{l}$, let $a = k\frac{h}{l}$ and noting that $a = k$ when $h = l$ which → freefall,
   b) Calculate g (=k) for an appropriate set of corresponding data.
6. How close does the experimentally determined value of g compare with the accepted value of g in New York? (Explain discrepancies if any)
7. Why did Galileo use inclined plane? What additional difficulty did it introduce.
8. Is extrapolation to acceleration of freefall valid?

Station

AVIATION HIGH SCHOOL Exp. # 19 **APPLIED PHYSICS LABORATORY**

Team

> "Casimir has calculated that if The Physical Review continued to grow as rapidly as it did between 1945 and 1960, it would weigh more than the earth during the next century. The exponential rise of scientific literature starting with the 18th century has often been associated with the increase in the number of scientists. The number of scientists in America increased from about 8,000 in 1900 to more than 100,000 in 1960."
>
> A. Calandra

PROBLEM: To write-up a finished report based on data gathered at an earlier date by physical experimentation.

APPARATUS:	REFERENCES:
Slide Rule	APL library Lab. notes

MAKING THE REPORT:

1. Place appropriate heading at top of paper.
2. State problem.
3. List apparatus used in experiment.
4. List references: Author, Title, pages.
5. Retrace the procedure employed -- detailed sketches add to lucidity.
6. List data with units in tables
7. Show all required equations and computations.
8. Graphs should be large and clearly labeled.
9. Substantiate conclusions.
10. Answer all questions with complete sentences.
11. Conclude report with a list of things learned as a result of the experiment.

Station

AVIATION HIGH SCHOOL Exp.# ☐ **APPLIED PHYSICS LABORATORY**

Team

Name ______________________________

PROBLEM:

APPARATUS: REFERENCES:

than 100,000 in 1960."

A. Calandra

PROBLEM: To write-up a finished report based on data gathered at an earlier date by physical experimentation.

APPARATUS:	REFERENCES:
Slide Rule	APL library Lab. notes

MAKING THE REPORT:

1. Place appropriate heading at top of paper.
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3. List apparatus used in experiment.
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8. Graphs should be large and clearly labeled.
9. Substantiate conclusions.
10. Answer all questions with complete sentences.
11. Conclude report with a list of things learned as a result of the experiment.

Station Exp.# Team

⬡ AVIATION HIGH SCHOOL ☐ APPLIED PHYSICS LABORATORY ○

Name ______________________

PROBLEM:

APPARATUS: REFERENCES:

PROCEDURE:

SUMMATION:

> "The average physicist is made a little uncomfortable by thermodynamics... The laws of thermodynamics have a different feel from most other laws of the physicist. There is something more palpably verbal about them--they smell more of their human origin."
>
> P. W. Bridgman

> "A mathematician may say anything he pleases, but a physicist must be at least partially sane."
>
> Willard Gibbs

PROBLEM: To experimentally determine the value of absolute zero.

APPARATUS:

- 2 25 ml grad. cyl.
- 2 stoppers with tubes
- 2 Bunsen burners
- Triple beam balance
- 3 1000cc beakers
- 2 arms with rubber bands
- Ice
- 2 tubeseals
- 3 iron stands
- 3 thermometers
- 2 ring supports

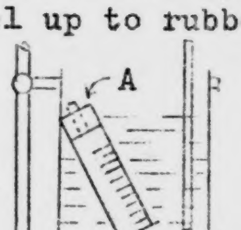
REFERENCES:

1. Holton, Found. of Modern Physical Science, pp. 369-71
2. Gamow, Physics, pp. 148-9

GATHERING THE DATA:

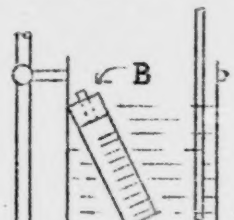
1. Measure the total volumes of each 25ml graduated cylinder (A and B) --include volume above graduations to stopper and volume of glass tube in stopper. DO NOT ALLOW MOISTURE TO ENTER GRADUATED CYLINDER!

2. Place tilted 25ml graduated cylinder in 1000cc beaker as shown--water level up to rubber stopper.



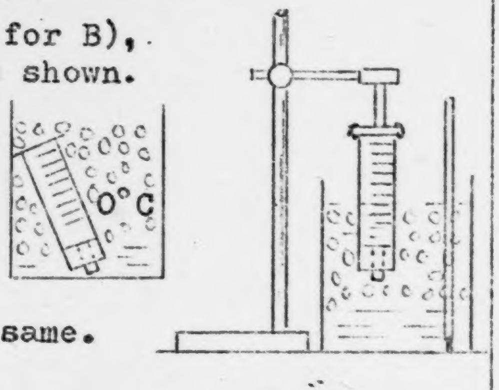
adjust for boiling water & permit air in grad. cylinder to reach 100°C.

NO MOISTURE IN CYLINDERS!



adjust for constant 50°C water & permit air in grad. cylinder to acquire this temperature.

3. a) Seal tube entering graduated cylinder A (repeat for B), invert the cylinder, and submerge in ice water as shown.
   b) Remove seal--as air in the graduated cylinder cools, water enters.
   c) When air in cylinder has cooled to 0°C (or the temperature of the ice-water mixture), fasten cylinder base to iron stand arm with rubber bands and adjust cylinder so that water levels in the beaker and the graduated cylinder are the same.
   d) Measure air volume at 0°C.



4. a) Place finger over tube to seal water in cylinder and remove from ice water.

> "A mathematician may say anything he pleases, but a physicist must be at least partially sane."
>
> Willard Gibbs

PROBLEM: To experimentally determine the value of absolute zero.

APPARATUS:

- 2 25 ml grad. cyl.
- 2 stoppers with tubes
- 2 Bunsen burners
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- Ice
- 2 tubeseals
- 3 iron stands
- 3 thermometers
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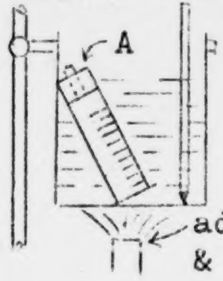
REFERENCES:

1. Holton, Found. of Modern Physical Science, pp. 369-71
2. Gamow, Physics, pp. 148-9

GATHERING THE DATA:

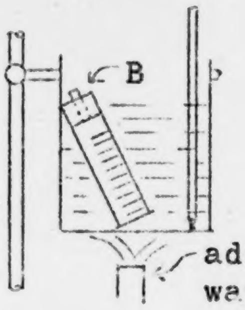
1. Measure the total volumes of each 25ml graduated cylinder (A and B) --include volume above graduations to stopper and volume of glass tube in stopper. DO NOT ALLOW MOISTURE TO ENTER GRADUATED CYLINDER!

2. Place tilted 25ml graduated cylinder in 1000cc beaker as shown--water level up to rubber stopper.



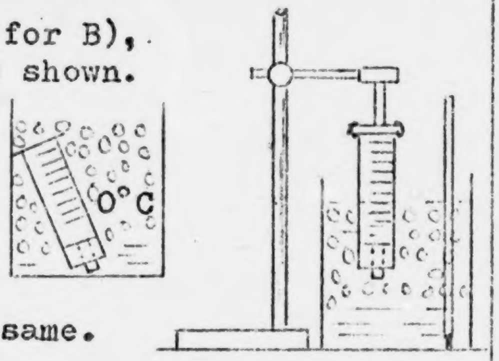
adjust for boiling water & permit air in grad. cylinder to reach 100°C.

NO MOISTURE IN CYLINDERS!



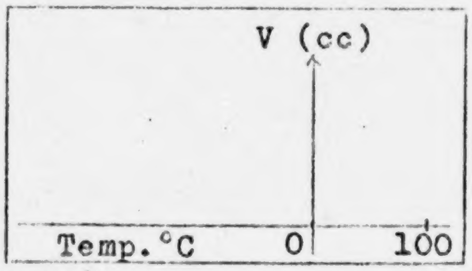
adjust for constant 50°C water & permit air in grad. cylinder to acquire this temperature.

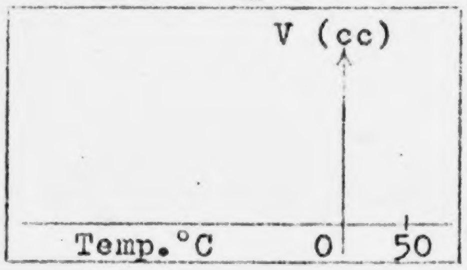
3. a) Seal tube entering graduated cylinder A (repeat for B), invert the cylinder, and submerge in ice water as shown.
   b) Remove seal--as air in the graduated cylinder cools, water enters.
   c) When air in cylinder has cooled to 0°C (or the temperature of the ice-water mixture), fasten cylinder base to iron stand arm with rubber bands and adjust cylinder so that water levels in the beaker and the graduated cylinder are the same.
   d) Measure air volume at 0°C.



4. a) Place finger over tube to seal water in cylinder and remove from ice water.
   b) Dry off outside of cylinder and measure its mass (including water drawn in from ice water).
   c) Fill cylinder completely with water using squeeze bottle and again measure its mass.
   d) Remove stopper from cylinder, empty out water, dry all parts, and measure total mass of cylinder, stopper, and glass tube.
   e) Calculate air volumes in cc. using masses of steps b, c, and d.

5. Using data of step #3:
   a) Plot points for 100°C vol. & 0°C volume & join with st. line.
   b) Extrapolate to temp. associated with zero vol. (abs. zero).
   c) Repeat a & b for 0°C and 50°C.





6. Repeat step #5 using data of step #4 (use same paper but color differently).

SUMMATION:

1. Which graph yields absolute zero most accurately? Explain.
2. Does air vol. disappear at abs. 0? Was extrapolation valid? Explain.

Station

AVIATION HIGH SCHOOL

Exp.# 21

APPLIED PHYSICS LABORATORY

Team

> "In his writings, he (Galileo) describes experiments he never made. He advocated the heliocentric theory even though, in the stage in which Copernicus left it, the theory did not yet accord well with observations. In describing some experiments on motion along an inclined plane Galileo did not give actual data but said that the results agreed with theory to a degree of accuracy that was incredible in view of the poor clocks available in his time."
>
> Morris Kline

PROBLEM: To measure the acceleration of gravity.

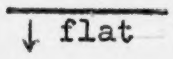
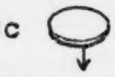
APPARATUS:

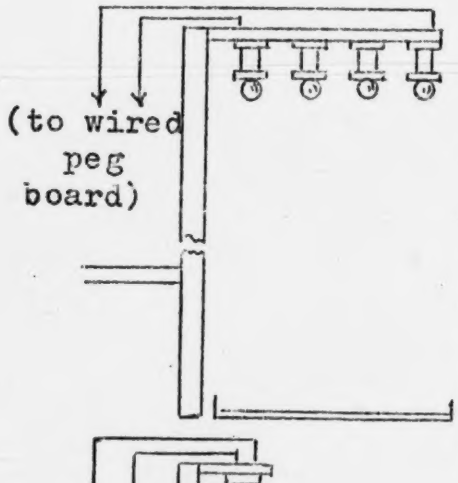
Wired peg board
Free-fall support
3/4" dia. ironball
Iron plugged spheres
Magnetic arm
Spring contacts & arm
Ping pong ball, paper & disks
Electric timer
Plumb bob
6 clip leads
Table leads
DC supply
Catch bucket

REFERENCES:

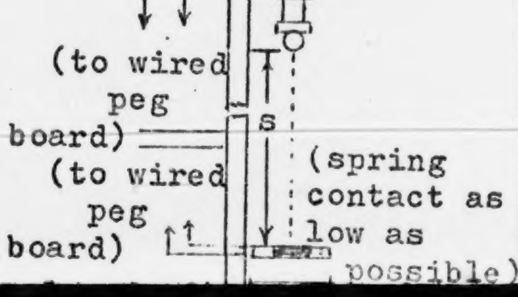
1. Stollberg, Physics Fundamentals, p. 24
2. PSSC, Physics, pp. 336-8
3. White, Modern College Physics, pp. 34-7
4. Beiser, Basic Concepts of Physics, pp. 15-8

GATHERING THE DATA:

1. Drop ping pong ball. & sheet of paper a)  flat b) edgewise c) crumbled
   (observe rate of fall of each)
2. a) Drop cardboard disc  and penny & observe rate of fall for each.
   b) Repeat with cardboard disc on top of penny.
3. Mount magnetic arm at top of free fall support.
   a) Wire circuit as per instructions on peg board.
   b) Close switch and mount wood, brass, iron, and aluminum spheres as shown.
   c) Open switch and observe rate of fall for the four spheres.
   d) Repeat several times.



4. Time the 3/4" diameter iron ball through prescribed free fall distances.
   a) Line up ball and spring contact face with plumb bob. (Use magnet with hole)
   b) Connect wires to electric timer and wired peg board.
   c) Release ball according to peg board instructions & record data in table: (Make three trials)
   d) Repeat above for free falls of 1.5m, 1m, and 0.5m.



> along an inclined plane Galileo did not give actual data but said that the results agreed with theory to a degree of accuracy that was incredible in view of the poor clocks available in his time."
>
> Morris Kline

PROBLEM: To measure the acceleration of gravity.

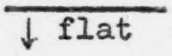
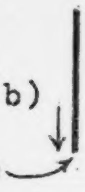
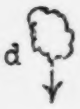
APPARATUS:

Wired peg board
Free-fall support
3/4" dia. ironball
Iron plugged spheres
Magnetic arm
Spring contacts & arm
Ping pong ball, paper & disks
Electric timer
Plumb bob
6 clip leads
Table leads
DC supply
Catch bucket

REFERENCES:

1. Stollberg, Physics Fundamentals, p. 24
2. PSSC, Physics, pp. 336-8
3. White, Modern College Physics, pp. 34-7
4. Beiser, Basic Concepts of Physics, pp. 15-8

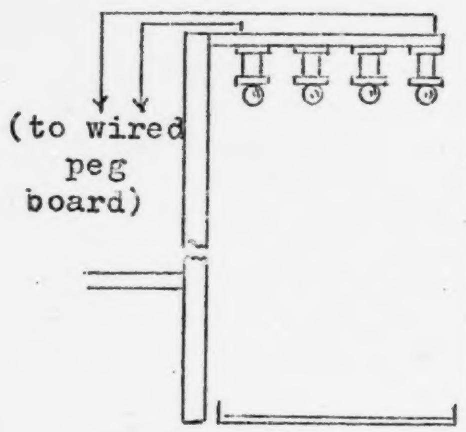
GATHERING THE DATA:

1. Drop ping pong ball. & sheet of paper a)  b)  c) crumbled 
   (observe rate of fall of each)

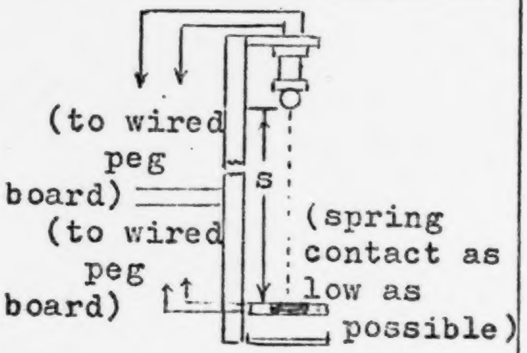
2. a) Drop cardboard disc and penny & observe rate of fall for each.

   b) Repeat with cardboard disc on top of penny.

3. Mount magnetic arm at top of free fall support.
   a) Wire circuit as per instructions on peg board.
   b) Close switch and mount wood, brass, iron, and aluminum spheres as shown.
   c) Open switch and observe rate of fall for the four spheres.
   d) Repeat several times.



4. Time the 3/4" diameter iron ball through prescribed free fall distances.
   a) Line up ball and spring contact face with plumb bob. (Use magnet with hole)
   b) Connect wires to electric timer and wired peg board.
   c) Release ball according to peg board instructions & record data in table:
   (Make three trials)
   d) Repeat above for free falls of 1.5m, 1m, and 0.5m.



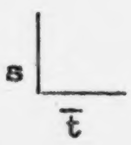
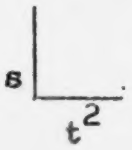
Distance s	t (sec) 1	2	3	Av. t	t^2	g
2m						
1.5m						
1m						
0.5m						

   e) Let $g = a$
   Calculate g using:

$$s = v_i t + \frac{at^2}{2}$$

5. Time 2m free fall for brass and aluminum spheres.

SUMMATION:

1. According to experimental data, how did the rates of fall of the assorted spheres compare?
2. Plot graphs  

3. What, if any, is the value of the constant of proportionality?
4. Now that g has been measured, react to Morris Kline's provocative comment at the beginning of this experiment.

Station

Exp.# 22

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Of all the intellectual hurdles which the human mind has been faced with and has overcome in the last fifteen hundred years, the one which seems to me to have been the most amazing in character and the most stupendous in the scope of its consequences is the one relating to the problem of motion."
>
> Herbert Butterfield

PROBLEM: To experimentally examine the motion of a pendulum.

APPARATUS:

Pendulum support & arm
Tape timer & support
2 100cm strips of tape
1½v. battery & leads
2 C clamps
Heavy metal ball
Stop watch
Wrench
Graph paper
Meter stick
mm ruler

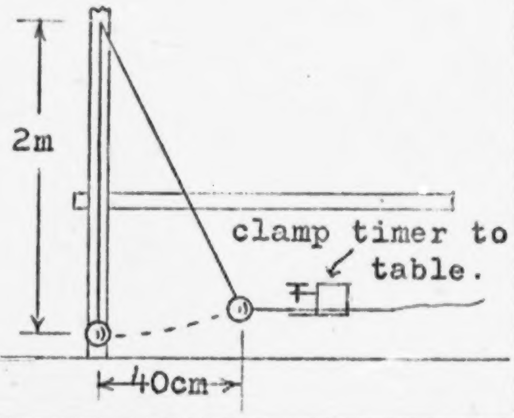
REFERENCES:

1. Taffel, Physics Lab. Manual, pp. 41-4
2. Thomas, Calculus & Analytic Geometry, pp. 34-8
3. Kline, Calculus I, pp. 97-8

GATHERING THE DATA:

1. Adjust timer.
   a) Raise striker until when operating it makes no imprint on tape.
   b) Gradually turn down striker a half turn at a time until it makes a clear impression on the tape.
   Note: 4 or 5 imprints can be made on each tape by moving the guide laterally--label each record for future reference.
2. Calibrate the timer--determine its period of vibration by:
   a) Manually drawing the tape through the guide for an accurately timed interval (2 or 3 seconds).
   b) Counting the spaces between dots.
   c) Dividing the time interval by the number of spaces.
3. Set up pendulum--2m length.
4. Make several ½" folds at end of tape, cover with tape & punch hole through center as shown.

5. Connect tape to pendulum bob hook after threading tape through timer.
6. Off set bob 40cm, connect battery to timer, release pendulum, & stop after slightly more than 1/2 cycle.
7. Reset tape and repeat steps #5 & #6 for several more trials.
8. Mark every fifth dot after the starting dot.



9. Insert data in table:

Dot	t to o dot	Δs(4 spaces/2 on each side)	Δt(for 4 spaces)	v= Δs/Δt	a
5th					
10th					

relating to the problem of motion."

Herbert Butterfield

PROBLEM: To experimentally examine the motion of a pendulum.

APPARATUS:

Pendulum support & arm
Tape timer & support
2 100cm strips of tape
1½v. battery & leads
2 C clamps
Heavy metal ball
Stop watch
Wrench
Graph paper
Meter stick
mm ruler

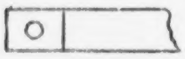
REFERENCES:

1. Taffel, Physics Lab. Manual, pp. 41-4
2. Thomas, Calculus & Analytic Geometry, pp. 34-8
3. Kline, Calculus I, pp. 97-8

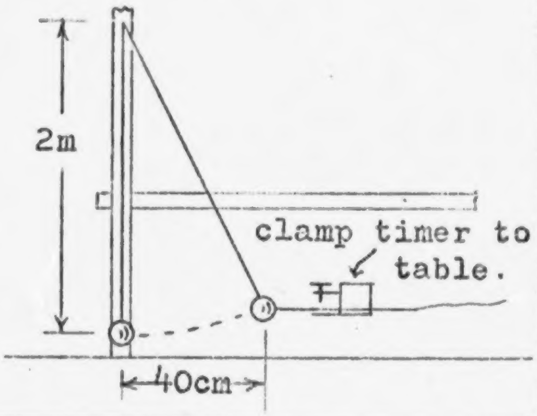
GATHERING THE DATA:

1. Adjust timer.
   a) Raise striker until when operating it makes no imprint on tape.
   b) Gradually turn down striker a half turn at a time until it makes a clear impression on the tape.

   Note: 4 or 5 imprints can be made on each tape by moving the guide laterally--label each record for future reference.
2. Calibrate the timer--determine its period of vibration by:
   a) Manually drawing the tape through the guide for an accurately timed interval (2 or 3 seconds).
   b) Counting the spaces between dots.
   c) Dividing the time interval by the number of spaces.
3. Set up pendulum--2m length.
4. Make several ½" folds at end of tape, cover with tape & punch hole through center as shown.



5. Connect tape to pendulum bob hook after threading tape through timer.
6. Off set bob 40cm, connect battery to timer, release pendulum, & stop after slightly more than 1/2 cycle.
7. Reset tape and repeat steps #5 & #6 for several more trials.
8. Mark every fifth dot after the starting dot.



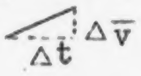
9. Insert data in table:

Dot	t to o dot	Δs(4 spaces/2 on each side)	Δt(for 4 spaces)	$v = \Delta s/\Delta t$	a
5th					
10th					

10. Plot graphs.

$\overline{v}$
t
$\overline{a}$
t

where $\overline{a}$ = slope of graph $\overline{v}$ vs t



SUMMATION:

1. Since $\overline{a} = \dfrac{v_f - v_i}{t_f - t_i}$ and $a = \overline{a}_{\Delta t \to 0} = \dfrac{\Delta v}{\Delta t}$, what kind of line is approached as the line joining points v_f, t_f, and v_i, t_i satisfies the condition $\Delta t \to 0$?
2. What kind of mathematics is involved when $\Delta t \to 0$?
3. Is acceleration value duplicated during one-half of the cycle? If so, what is the relation of such points to the mid point of pendulum swing
4. According to tape, what is time for a cycle? How does this agree with time derived from equation $T = 2\pi\sqrt{\frac{L}{g}}$
5. At what points is: a) velocity greatest? least?
   b) acceleration greatest? least?

Station ⬡ AVIATION HIGH SCHOOL Exp.# 23 APPLIED PHYSICS LABORATORY Team ○

> "The laws of physics are proposed to the student by the teacher or the textbook, or both, as dogmatic truths. The student is expected to take them on faith... This is a fine way to teach theology, but it is a pretty sorry way of teaching science."
>
> Nathaniel H. Frank

PROBLEM: To experimentally determine the relationship between acceleration and mass, and to derive the force unit using Atwood's machine.

APPARATUS:

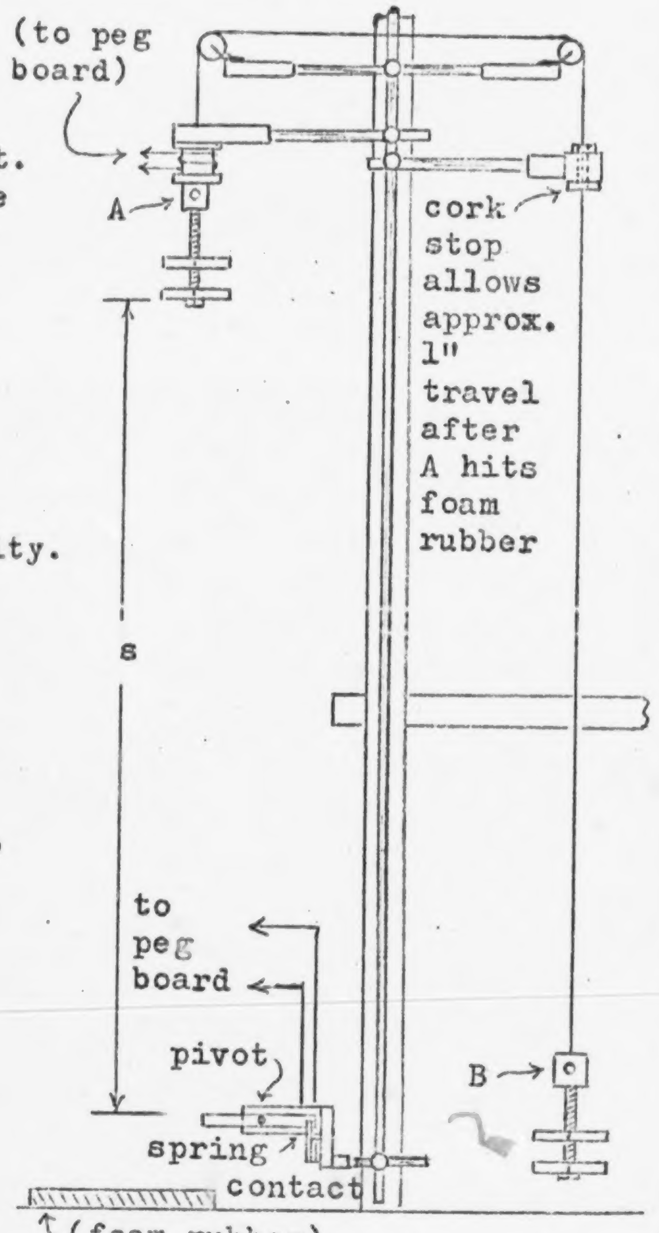
2 mass holders
Pulley assembly
Electromagnet assembly
Spring contact assembly
2 meter sticks (or tape)
Triple beam balance
Peg board & electric timer
2 slot-gm sets
Cord
Graph paper
Clip leads
Cork stop
Foam rubber

REFERENCES:

1. White, Modern College Physics, pp. 41-4
2. Stollberg, Physics, pp. 44-6

GATHERING THE DATA:

1. Measure masses of mass holders A and B.
2. a) Attach pulley assembly at top of support.
   b) Line up electromagnet directly below the pulley assembly.
   c) Connect cord through electromagnet and cork stop to mass holders as shown.
   d) Mount spring switch close to floor--a carefully measured s distance (approx. 2 meters).
3. Compensate for friction by adding measured mass to A until when it is given a gentle push it moves downward with uniform velocity.
4. a) Connect spring switch and electromagnet leads to peg board as per peg board instructions.
   b) Connect table supply to peg board.
   c) Separate spring contacts with insulated arm.
5. Place unbalanced 50gm mass on A, raise A to electromagnet, and energize electromagnet after A stops vibrating.
6. a) Release A by pressing momentary switch.
   b) Register masses, s, and time in table. (Use average t of several trials.)
   c) Calculate acceleration a*.



Total Mass (A + B)	Unbalanced Mass	s	t	t^2	$a^* = \frac{2s}{t^2}$
	50 gm				

Nathaniel H. Frank

PROBLEM: To experimentally determine the relationship between acceleration and mass, and to derive the force unit using Atwood's machine.

APPARATUS:

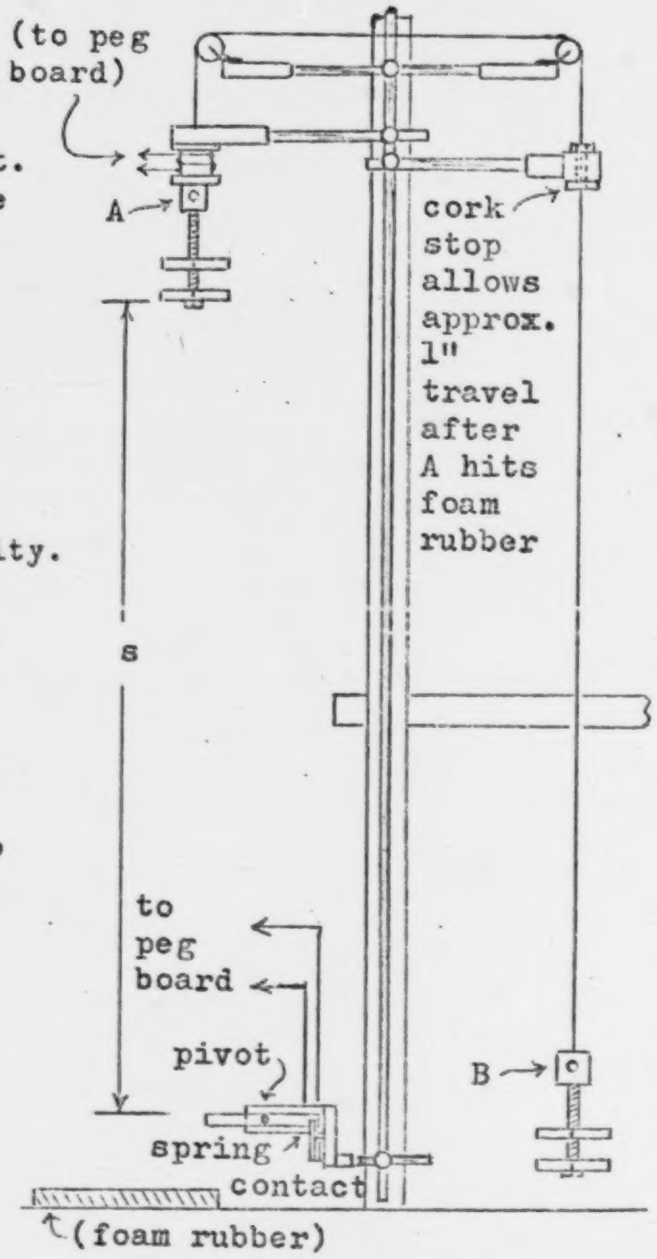
- 2 mass holders
- Pulley assembly
- Electromagnet assembly
- Spring contact assembly
- 2 meter sticks (or tape)
- Triple beam balance
- Peg board & electric timer
- 2 slot-gm sets
- Cord
- Graph paper
- Clip leads
- Cork stop
- Foam rubber

REFERENCES:

1. White, *Modern College Physics*, pp. 41-4
2. Stollberg, *Physics*, pp. 44-6

GATHERING THE DATA:

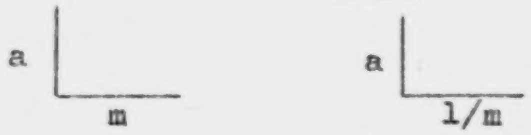
1. Measure masses of mass holders A and B.
2. a) Attach pulley assembly at top of support.
   b) Line up electromagnet directly below the pulley assembly.
   c) Connect cord through electromagnet and cork stop to mass holders as shown.
   d) Mount spring switch close to floor--a carefully measured s distance (approx. 2 meters).
3. Compensate for friction by adding measured mass to A until when it is given a gentle push it moves downward with uniform velocity.
4. a) Connect spring switch and electromagnet leads to peg board as per peg board instructions.
   b) Connect table supply to peg board.
   c) Separate spring contacts with insulated arm.
5. Place unbalanced 50gm mass on A, raise A to electromagnet, and energize electromagnet after A stops vibrating.
6. a) Release A by pressing momentary switch.
   b) Register masses, s, and time in table. (Use average t of several trials.)
   c) Calculate acceleration a*.



Total Mass (A + B)	Unbalanced Mass	s	t	t^2	$a^* = \frac{2s}{t^2}$
	50 gm				
	50 gm				
	50 gm				

*assuming acceleration constant

7. Repeat step #6, adding masses to both A and B in 50gm steps.
8. Plot graphs:



SUMMATION:

1. a) Which graph yields an easily understood relationship between the variables?
   b) What is the relationship?
   c) What name is given to the constant of proportionality?
2. Which law has been experimentally demonstrated? Explain.
3. a) Which law is involved in step #3 "Gathering the Data" ?
   b) Explain how the effects of friction are compensated for.
   c) Explain how acceleration can be shown constant during each trial in 6 & 7. (use prior APL experiment experience)

Station ⬡ Exp.# 24 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "If I have seen a little further than others it is because I have stood on the shoulders of giants... I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the sea shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary whilst the great ocean of truth lay all undiscovered before me."
>
> Newton

PROBLEM: To experimentally examine the relationship between force and acceleration.

APPARATUS:

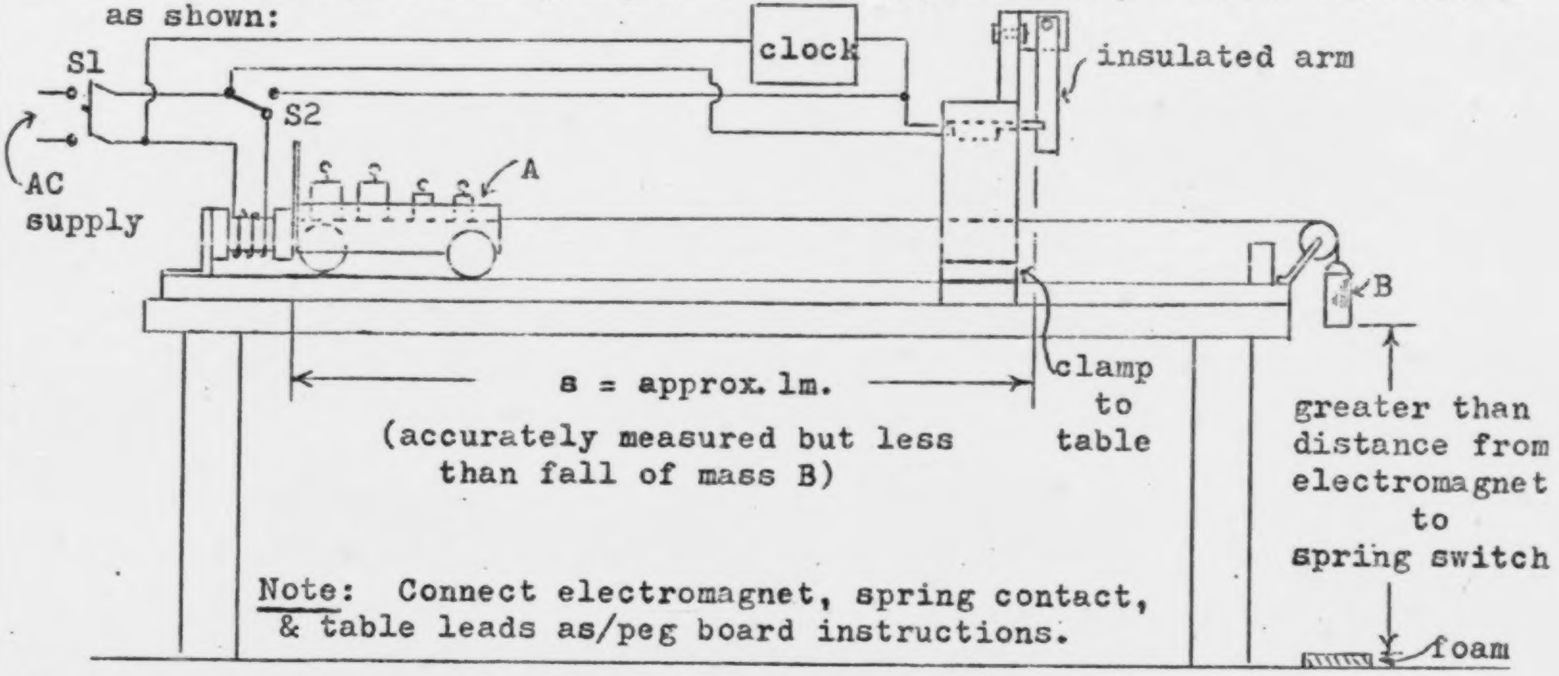
2 gm mass sets	Level
Graph paper	Cart
Spring switch assembly	Cord
Formica board assembly	C clamp
Triple beam balance	Can
Peg board & electric timer	

REFERENCES:

1. Taffel, Physics, pp. 103-5
2. White, Modern College Physics, pp. 41-4
3. MacLachlan, Matter and Energy, pp. 72-74

GATHERING THE DATA:

1. a) Measure cart mass with 2kg load and record.
   b) Measure mass of can and record.
2. a) Set formica board parallel to and about 4" in from the laboratory table's edge.
   b) Level the board (use shims if necessary).
3. Set electromagnet and spring switch for approximately 1 meter cart travel as shown:


clock
S1
S2
insulated arm
AC supply
A
B
s = approx. 1m.
(accurately measured but less than fall of mass B)
clamp to table
greater than distance from electromagnet to spring switch
foam

Note: Connect electromagnet, spring contact, & table leads as/peg board instructions.

4. a) Separate spring contacts with insulated arm.
   b) Hold cart against electromagnet and close switch S1.
   c) Connect can to string--provide for maximum fall.
5. a) Release cart by pressing momentary switch S2 and measure time to travel distance s.
   b) Record data in table and make necessary calculations.

Total Accelerated Mass	Unbalanced Mass (F)	s	t	a* = 2s

> finding a smoother pebble or a prettier shell than ordinary whilst the great ocean of truth lay all undiscovered before me."
>
> Newton

PROBLEM: To experimentally examine the relationship between force and acceleration.

APPARATUS:

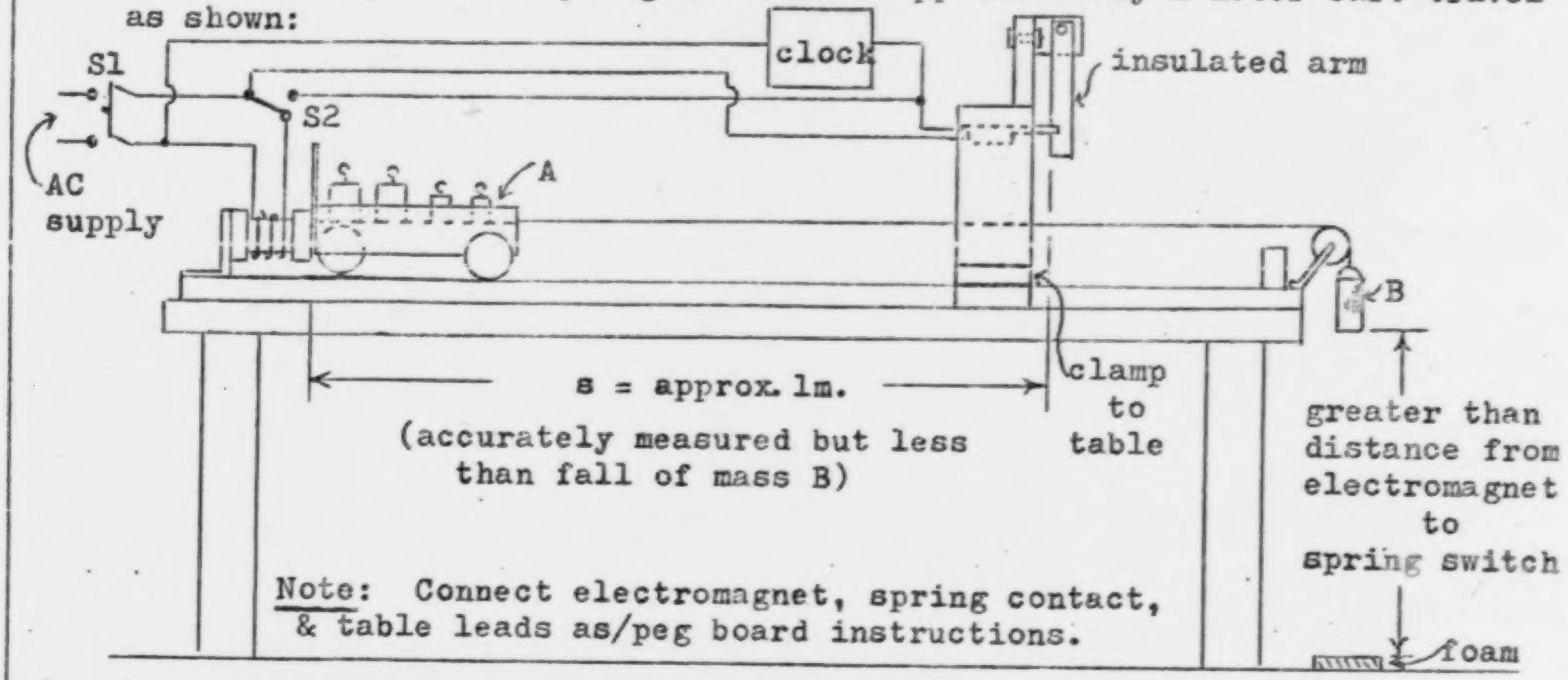
2 gm mass sets	Level
Graph paper	Cart
Spring switch assembly	Cord
Formica board assembly	C clamp
Triple beam balance	Can
Peg board & electric timer	

REFERENCES:

1. Taffel, Physics, pp. 103-5
2. White, Modern College Physics, pp. 41-4
3. MacLachlan, Matter and Energy, pp. 72-74

GATHERING THE DATA:

1. a) Measure cart mass with 2kg load and record.
   b) Measure mass of can and record.
2. a) Set formica board parallel to and about 4" in from the laboratory table's edge.
   b) Level the board (use shims if necessary).
3. Set electromagnet and spring switch for approximately 1 meter cart travel as shown:


S1
S2
clock
insulated arm
AC supply
A
B
s = approx. 1m.
(accurately measured but less than fall of mass B)
clamp to table
greater than distance from electromagnet to spring switch
foam
Note: Connect electromagnet, spring contact, & table leads as/peg board instructions.

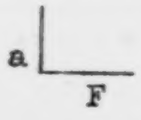
4. a) Separate spring contacts with insulated arm.
   b) Hold cart against electromagnet and close switch S1.
   c) Connect can to string--provide for maximum fall.
5. a) Release cart by pressing momentary switch S2 and measure time to travel distance s.
   b) Record data in table and make necessary calculations.

Total Accelerated Mass Cart A + Can B (kg)	Unbalanced Mass (F) Can B (kg)	s Meters	t Sec.	$a^* = \frac{2s}{t^2}$
	Can B			
	Can B + 20 gm			
	etc.			

6. Repeat step #5--transferring in successive steps 20gm of mass from cart A to can B.

SUMMATION:

1. Plot graph.



Note: Force may be plotted in mass units. Explain.

2. Explain how assumption that acceleration a* is a constant can be experimentally justified.
3. According to experimental data:
   a) What is the relation between a and F?
   b) What is the frictional force of the wheels and pulley?

(IF TIME PERMITS, REPEAT ENTIRE EXPERIMENT WITH LIGHTER CART LOAD)

Station ⬡ AVIATION HIGH SCHOOL Exp. # 25 APPLIED PHYSICS LABORATORY Team ○

> "Robert Hooke ... originated many physical ideas but perfected few of them. He had an irritable temper, and made many virulent attacks on Newton and other men of science, claiming that work published by them was due to him."
>
> Harvey White
>
> "For fear of having his discovery 'stolen' by unscrupulous scientists, he published it at the end of one of his lectures in the form of an anagram 'ce iii nosss tt uv'. Later he divulged the proper order of the letters to be 'ut tensio sic vis' ... Elongation is proportional to tension."
>
> Henry Margenau

PROBLEM: To experimentally derive Hooke's Law and to determine the stiffness constants of springs.

APPARATUS:

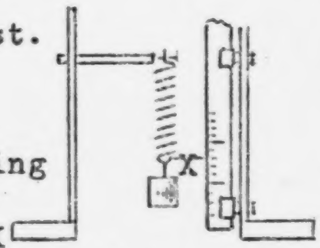
Springs
Load saddle
1½v. battery
Meter stick
Pine boards
2 C clamps
Depth micrometer & holder
Circuit board & leads
Hook-wts. 10-500 gm
Slot-wts. 10-500 gm
Spring rods
3 iron stands & clamps

REFERENCES:

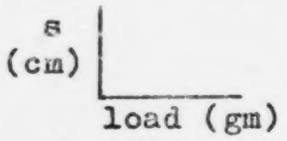
1. White, Modern College Physics, p. 175
2. Dull, Modern Physics, pp. 179-80
3. Stollberg, Physics Fundamentals, pp. 237-8
4. Arons, Development of Concepts of Physics, pp. 164-7

GATHERING THE DATA:

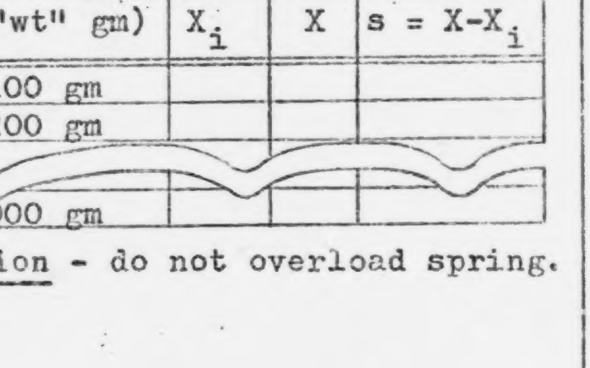
1. a) Mount spring A for test.
   b) Note unloaded spring pointer reading X_i.
   c) Successively load spring in 100 gm steps.
   d) Note pointer reading X for each load--record results in table. Caution - do not overload spring.
   e) Plot graph:



F ("wt" gm)	X_i	X	$s = X-X_i$
100 gm			
200 gm			
1000 gm			



2. Repeat step #1 for springs B, C, and D (use appropriate loads & increments)
3. Check board deflection:
   a) note micrometer reading for unloaded board. (use reading which just lights bulb)
   b) add 100 gm load--adjust micrometer to check deflection.
   c) repeat b for successive 100 gm increments.
   Caution - do not release load before turning micrometer back.
   - do not overload board.
   d) record data in table.
   e) plot graph: deflection vs. load



Load	Deflection			
	A	B	C	D
100gm				
200gm				

4. Repeat #3 for boards B, C, and D.

Harvey White

"For fear of having his discovery 'stolen' by unscrupulous scientists, he published it at the end of one of his lectures in the form of an anagram 'ce iii nosss tt uv'. Later he divulged the proper order of the letters to be 'ut tensio sic vis' ... Elongation is proportional to tension."

Henry Margenau

PROBLEM: To experimentally derive Hooke's Law and to determine the stiffness constants of springs.

APPARATUS:

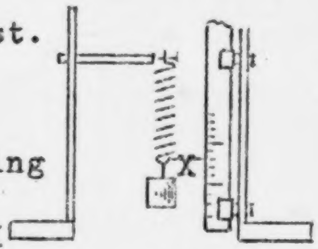
Springs
Load saddle
1½v. battery
Meter stick
Pine boards
2 C clamps
Depth micrometer & holder
Circuit board & leads
Hook-wts. 10-500 gm
Slot-wts. 10-500 gm
Spring rods
3 iron stands & clamps

REFERENCES:

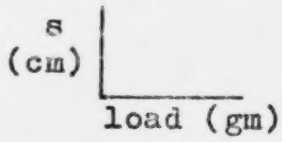
1. White, Modern College Physics, p. 175
2. Dull, Modern Physics, pp. 179-80
3. Stollberg, Physics Fundamentals, pp. 237-8
4. Arons, Development of Concepts of Physics, pp. 164-7

GATHERING THE DATA:

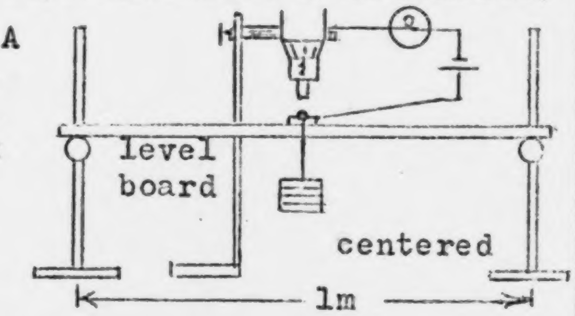
1. a) Mount spring A for test.
   b) Note unloaded spring pointer reading X_i.
   c) Successively load spring in 100 gm steps.
   d) Note pointer reading X for each load--record results in table. Caution - do not overload spring.
   e) Plot graph:



F ("wt" gm)	X_i	X	$s = X - X_i$
100 gm			
200 gm			
1000 gm			



2. Repeat step #1 for springs B, C, and D (use appropriate loads & increments)
3. Check board deflection:
   a) note micrometer reading for unloaded board. (use reading which just lights bulb)
   b) add 100 gm load--adjust micrometer to check deflection.
   c) repeat b for successive 100 gm increments.
   Caution - do not release load before turning micrometer back.
   - do not overload board.
   d) record data in table.
   e) plot graph: deflection vs. load
4. Repeat #3 for boards B, C, and D.
5. Repeat #3 for 1/2 meter length of board A.



Load	Deflection			
	A	B	C	D
100gm				
200gm				
etc.				

SUMMATION:

1. According to data and graphs, what is the relationship between force (load) and deflection in spring experiments?
2. Determine k--the constant of proportionality (or stiffness constant) for each spring.
3. For a board what effect does:
   a) halving length have on the deflection?
   b) doubling width have on the deflection?
   c) doubling depth have on the deflection?
4. For gold purchased in Alaska and sold in San Francisco, would it be advantageous to use a spring balance calibrated in Washington, D. C.--rather than an equal arm balance?
5. Devise a test for determing the elasticity of a rubber band! Try it.
6. Under what restriction does Hooke's law operate?

Station

Exp.# 26

AVIATION HIGH SCHOOL **APPLIED PHYSICS LABORATORY**

Team

> "When a particle is acted upon by three forces, the necessary and sufficient condition for equilibrium is that the three forces lie in one plane and that each force be proportional to the sine of the angle between the other two."
>
> Fr. Lani's Theorem (1640-1715)

PROBLEM: To experimentally test theories regarding the composition and the resolution of forces.

APPARATUS:

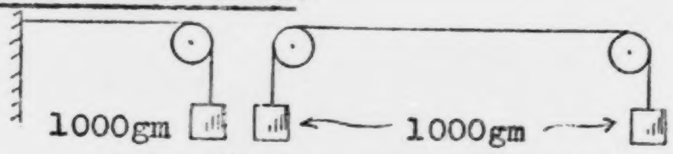
2 spring scales	Cord
2 sets of gm "wts"	Ring
Heavy iron ball	Iron stand
Large protractor & arm	Graph paper
Table supports & crossbar	Level
2 pulleys	

REFERENCES:

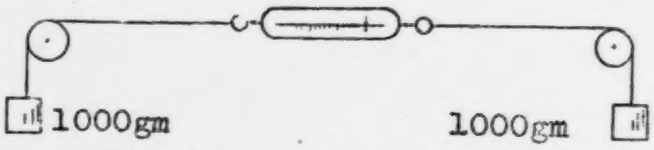
1. Beiser, Basic Concepts of Physics, pp. 39-44
2. White, Modern College Physics, pp. 57-60
3. Halliday & Resnick, Physics, pp. 13-19

GATHERING THE DATA:

1.

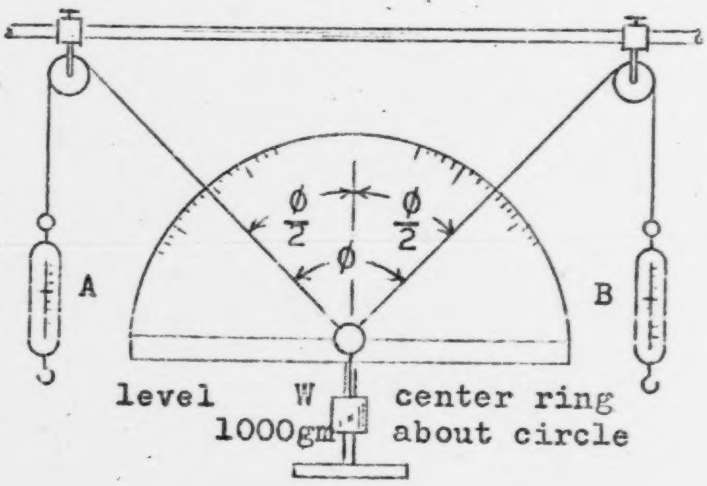


What is cord tension?



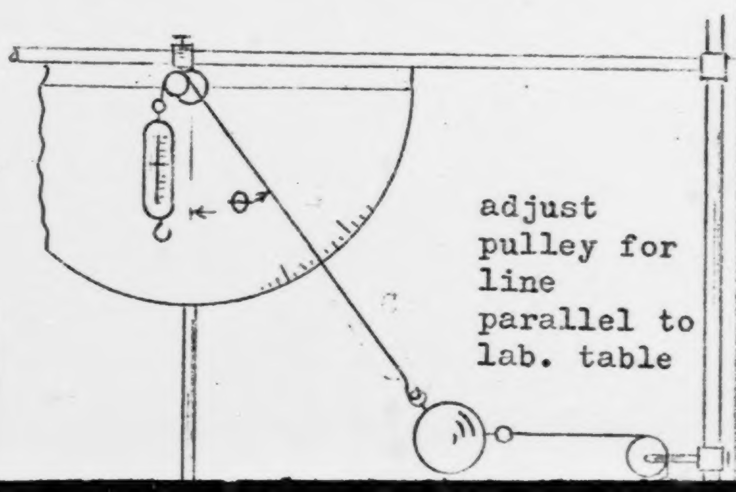
Roughly check cord tension.

2. a) Set up apparatus as shown.
   b) Set angle ∅ = 20 & record scale readings A & B (include wt. of scale in each)
   c) Graphically determine the resultant & equilibrant of forces A & B. --record data in table.
   d) Repeat steps b & c for ∅ = 20°, 40°, 60°, 80°, 100°, & 120°.



∅	Force A gm	Force B gm	Equilibrant "gm"	
			graphical	actual
10°				
20°				

3. a) Set up apparatus as shown.
   b) Set angle θ = 0 and record scale readings C and D.
   c) Analytically determine the vertical and horizontal components of force C.
   d) Repeat steps b & c for θ = 5°, 10°, 15°, ...
   -- record data in table:



adjust pulley for line parallel to lab. table

θ	Force C "gm"	Analytic Vertical Component "gm"	Analytic Horizontal Component "gm"	W gm	Force D "gm"

Fr. Lani's Theorem (1640-1715)

PROBLEM: To experimentally test theories regarding the composition and the resolution of forces.

APPARATUS:

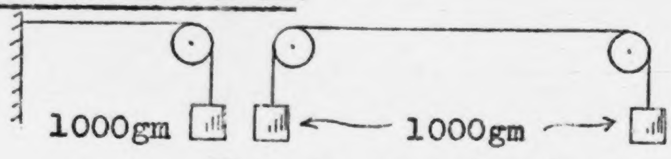
- 2 spring scales
- 2 sets of gm "wts"
- Heavy iron ball
- Large protractor & arm
- Table supports & crossbar
- 2 pulleys
- Cord
- Ring
- Iron stand
- Graph paper
- Level

REFERENCES:

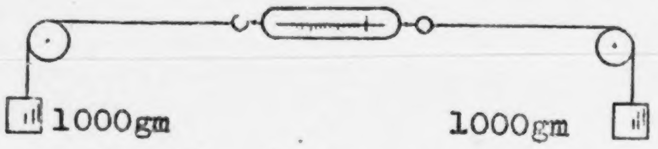
1. Beiser, Basic Concepts of Physics, pp. 39-44
2. White, Modern College Physics, pp. 57-60
3. Halliday & Resnick, Physics, pp. 13-19

GATHERING THE DATA:

1\.



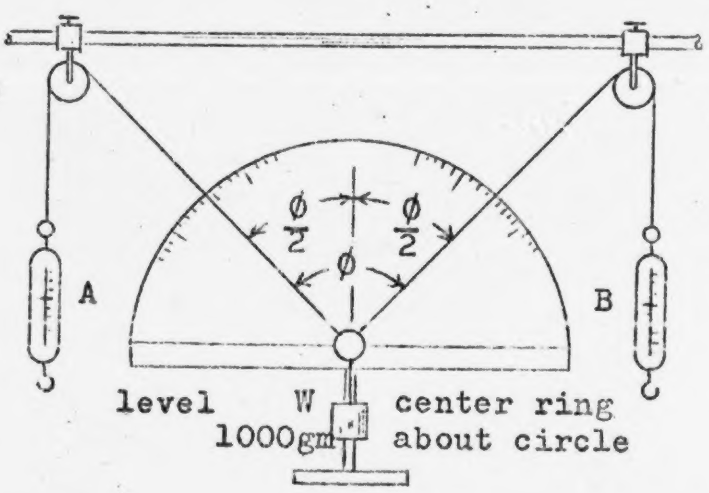
What is cord tension?



Roughly check cord tension.

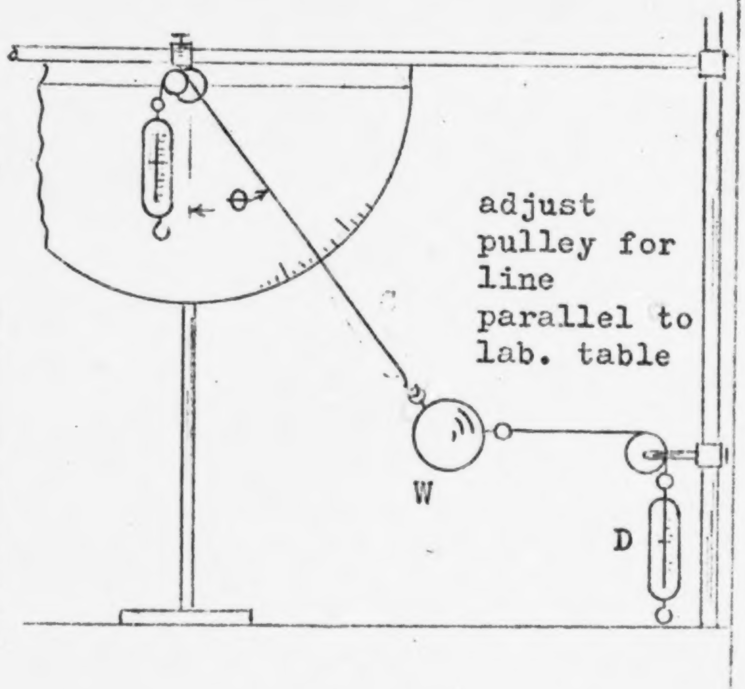
2. a) Set up apparatus as shown.
b) Set angle ϕ = 20 & record scale readings A & B (include wt. of scale in each)
c) Graphically determine the resultant & equilibrant of forces A & B. --record data in table.
d) Repeat steps b & c for $\phi = 20^\circ$, 40°, 60°, 80°, 100°, & 120°.

ϕ	Force A gm	Force B gm	Equilibrant "gm"	
			graphical	actual
10°				
20°				



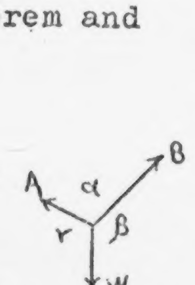
3. a) Set up apparatus as shown.
b) Set angle θ = 0 and record scale readings C and D.
c) Analytically determine the vertical and horizontal components of force C.
d) Repeat steps b & c for $\theta = 5^\circ$, 10°, 15°, ...
-- record data in table:

θ	Force C "gm"	Analytic Vertical Component "gm"	Analytic Horizontal Component "gm"	W gm	Force D "gm"
0°					
5°					



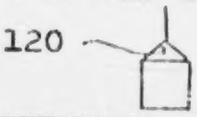
SUMMATION:

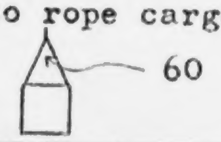
1. Other than the fact that grams are not weight units, does their use in this experiment interfere with the investigation of Fr. Lani's Theorem and force vectors? Explain.
2. Compare graphical and experimental results of step #2 above.
3. Compare analytical and experimental results of step #3 above.
4. Try verifying Fr. Lani's Theorem using the following set up:



(make all angles and forces different)

5. Which is the safer way to rope cargo? Why?





Station

AVIATION HIGH SCHOOL

Exp.# 27

APPLIED PHYSICS LABORATORY

Team

> "An isolated fact can be observed by all eyes; by those of the ordinary person as well as of the wise...Facts are sterile until there are minds capable of choosing between them and discerning those which conceal something...minds which under the bare fact see the soul of the fact."
>
> Henri Poincaré

PROBLEM: To experimentally and quantitatively determine the factors involved in moving objects in circular paths.

APPARATUS:

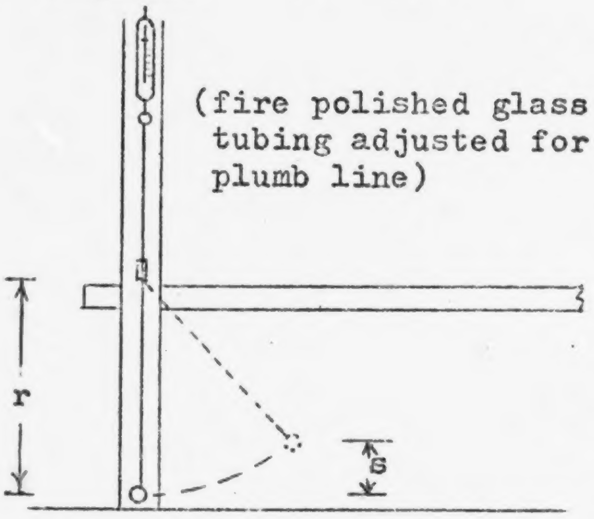
- 250 x 2 gm balance
- Nylon cord
- Clamp & holder for balance
- Fire polished glass tube & holder
- 1" dia. spheres--brass, steel, etc.

REFERENCES:

1. Holton, Found. of Mod. Physical Science, pp. 93-101
2. White, Modern College Physics, pp. 106-08
3. Gamow, Physics, pp. 82-5

GATHERING THE DATA:

1. Set up apparatus as shown in diagram.
2. Read scale. Pull sphere aside and observe scale reading as sphere moves to & fro.
3. a) Adjust fire polished glass tube for r = 1 meter.
   b) Pull brass sphere aside until s = 10 cm.
   c) Release & note maximum scale reading (take average of 5 trials)
   d) Pull brass sphere aside until s = 20cm, 30cm, etc. & repeat step #3c.
   e) Record results in table:

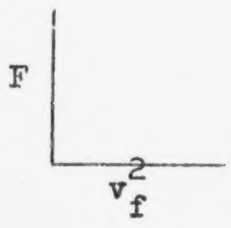


(fire polished glass tubing adjusted for plumb line)

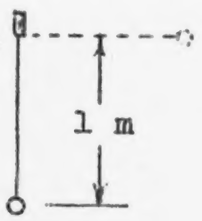
s(cm)	Mass(m) gm	m_s = max.reading	Centripetal "F"=m_s-m	v_f^2
10				
20				
100				

where: $v_f^2 \doteq 2gs$

f) Plot F vs. v_f^2



4. a) Check mass of brass sphere
   b) Hold brass sphere as shown, release and note max. scale reading. (Take average of 5 trials)
   c) Repeat steps #4a and 4b for iron, aluminum, lead, wood, etc. spheres.
   d) Record data in table:



Sphere Material	Mass m=gm	m_s = max.read. gm	Centripetal "Force" F = m_s - m

e) Plot:

> the soul of the fact."
>
> Henri Poincaré

PROBLEM: To experimentally and quantitatively determine the factors involved in moving objects in circular paths.

APPARATUS:

250 x 2 gm balance
Nylon cord
Clamp & holder for balance
Fire polished glass tube & holder
1" dia. spheres--brass, steel, etc.

REFERENCES:

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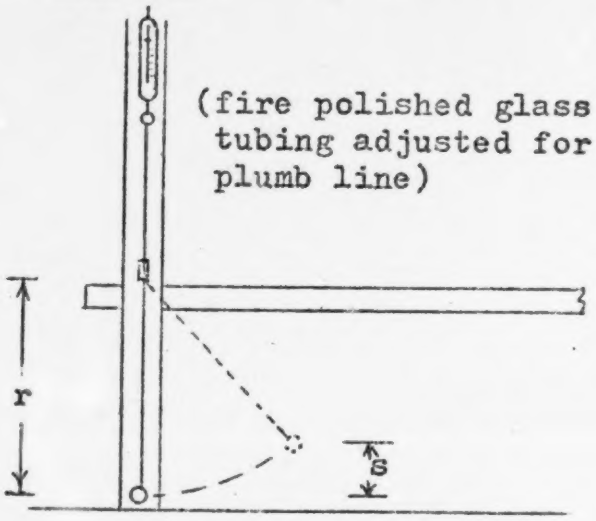
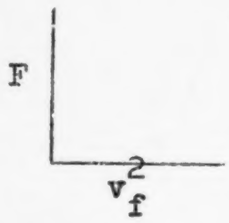
1. Set up apparatus as shown in diagram.
2. Read scale. Pull sphere aside and observe scale reading as sphere moves to & fro.
3. a) Adjust fire polished glass tube for $r = 1$ meter.
   b) Pull brass sphere aside until $s = 10$ cm.
   c) Release & note maximum scale reading (take average of 5 trials)
   d) Pull brass sphere aside until s = 20cm, 30cm, etc. & repeat step #3c.
   e) Record results in table:



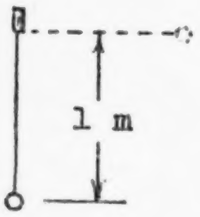
s(cm)	Mass(m) gm	m_s = max.reading	Centripetal "F"=m_s-m	v_f^2
10				
20				
100				

f) Plot F vs. v_f^2



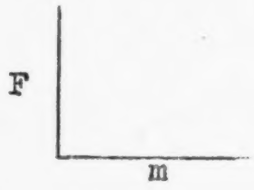
where: $v_f^2 \doteq 2gs$

4. a) Check mass of brass sphere
   b) Hold brass sphere as shown, release and note max. scale reading. (Take average of 5 trials)
   c) Repeat steps #4a and 4b for iron, aluminum, lead, wood, etc. spheres.
   d) Record data in table:



Sphere Material	Mass m=gm	m_s = max.read. gm	Centripetal "Force" $F = m_s - m$
brass			
iron			
wood			

e) Plot:



SUMMATION:

1. How accurately can the scale used be read?
2. What is the relationship between: a) F and v_f^2 ?
   b) F and m ?
3. Show that $v_f^2 \pm 2gs$
4. How are F, m, v^2, and r related in equation form? Justify.

Station ⬡ AVIATION HIGH SCHOOL Exp.# 28 APPLIED PHYSICS LABORATORY Team ○

> "In physics, as in mathematics, it is a great beauty if a theory can bring together apparently very different phenomena and show that they are closely connected; or even different aspects of the same thing, as when...Newton showed that the moon was falling like an apple."
>
> Sir George Thomson

PROBLEM: To examine the relationship between the mass, radius, velocity, and force of an object in uniform circular motion.

APPARATUS:

- Stop watch
- Triple beam balance
- Metronome
- Cord
- Graph paper
- Rubber stoppers #2,4,6,8,10,12
- Welch centripetal force apparatus

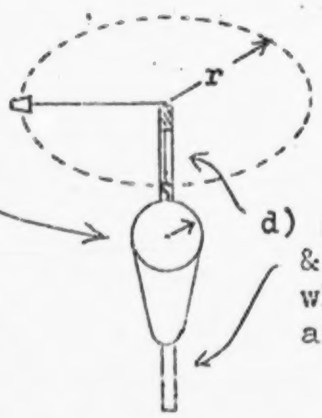
REFERENCES:

1. Holton, Found. of Modern Physical Science, pp. 93-101
2. White, Modern College Physics, pp. 106-8
3. Gamow, Physics, pp. 82-5

GATHERING THE DATA: (WEAR GOGGLES DURING EXPERIMENT!)

1. Compare variation of F with m:
   a) make loop at one end of cord, slip through hole of #2 stopper, and hook securely over stopper.

   b) pass other end of cord through glass tube at top of centripetal force apparatus and fasten via loop to Newton scale hook. (Cord--loop to loop approx. 1m.)
   c) adjust up and down for radius to center of stopper equal to 0.5m--include portion of radius due to stretching of Newton scale spring.



   d) grasp at top & bottom and whirl stopper around.
   e) an eccentric rocking motion is required --but when stopper is rotating at desired RPM, hold apparatus vertically motionless and quickly take Newton scale reading.
   f) set metronome for 100 RPM (check with stop watch), get #2 stopper revolutions to synchronize with the metronome and record Newtons in table.
   g) repeat for #4, 6, 8, 10, and 12 stoppers.

Stopper #	m(mass) kg	F_c (nt.)

2. Compare variation of F with r:
   a) whirl #8 stopper at 180 RPM with r = 0.2m radius.
   b) repeat a with 0.4, 0.6, & 0.8m radii (whenever radius is increas-

Stopper	r (meters)	RPM	F_c (nt)
#8	0.2	180	
#8	0.4	90	
#8	0.6	60	

like an apple."

Sir George Thomson

PROBLEM: To examine the relationship between the mass, radius, velocity, and force of an object in uniform circular motion.

APPARATUS:

- Stop watch
- Triple beam balance
- Metronome
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- Graph paper
- Rubber stoppers #2,4,6,8,10,12
- Welch centripetal force apparatus

REFERENCES:

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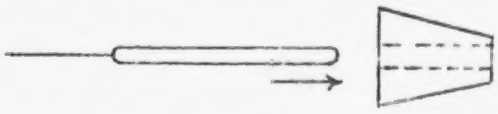
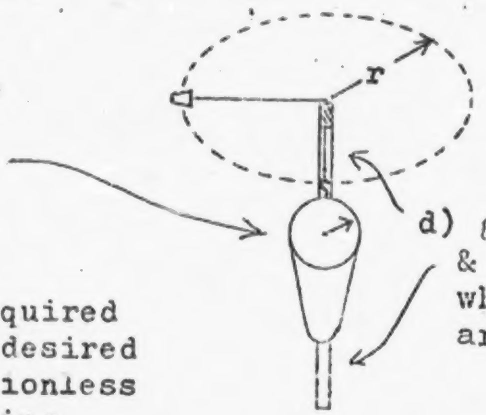
   f) set metronome for 100 RPM (check with stop watch), get #2 stopper revolutions to synchronize with the metronome and record Newtons in table.
   g) repeat for #4, 6, 8, 10, and 12 stoppers.





d) grasp at top & bottom and whirl stopper around.

Stopper #	m(mass) kg	F_c (nt.)

2. Compare variation of F with r:
   a) whirl #8 stopper at 180 RPM with r = 0.2m radius.
   b) repeat a with 0.4, 0.6, & 0.8m radii (whenever radius is increased, proportionally decrease RPM to keep speed constant)

Stopper	r (meters)	RPM	F_c (nt)
#8	0.2	180	
#8	0.4	90	
#8	0.6	60	
#8	0.8	45	

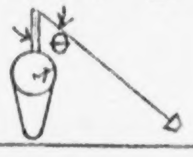
3. Compare variation of F with v & v^2:
   a) whirl #8 stopper with r = 0.5m and record data for 60 RPM, 100 RPM, 140 RPM, and 180 RPM.
   b) calculate velocity--m/sec. and $(\text{velocity})^2$ -- m^2/sec^2

Stopper	RPM	m/sec.	$m^2/sec.^2$
#8	60		
#8	100		
#8	140		
#8	180		

SUMMATION:

1. Plot graphs:

2. What is the relation between variables? Is there agreement with $F = \frac{mv^2}{r}$?
3. Does $\measuredangle\, \theta < 90°$ introduce error into data? Explain in detail.



(i.e. Line holding stopper not horizontal)

Station | AVIATION HIGH SCHOOL | Exp.# 29 | APPLIED PHYSICS LABORATORY | Team

> "Engineering investigations evidently are of no value unless they can be communicated to those to whom they are of interest. Thus the engineering report is an essential and important part of the work....an engineer....who is so much interested in the investigating work that he hates to 'waste' the time of making proper and complete reports....in general destroys the value of the work."
>
> Charles P. Steinmetz

> "It is a good rule to write a paper out, put it away for a week, and then revise it as if it had been written by a personal enemy, mercilessly excising the trite, the obvious, and the inconsequential, and straightening up every deviation from the straight and narrow road to the truth."
>
> L. W. McKeehan

PROBLEM: To write-up a finished report based on data gathered at an earlier date by physical experimentation.

APPARATUS:	REFERENCES:
Slide Rule	APL library Lab. notes

MAKING THE REPORT:

1. Place appropriate heading at top of paper.
2. State problem.
3. List apparatus used in experiment.
4. List references: Author, Title, pages.
5. Retrace the procedure employed -- detailed sketches add to lucidity.
6. List data with units in tables.
7. Show all required equations and computations.
8. Graphs should be large and clearly labeled.
9. Substantiate conclusions.
10. Answer all questions with complete sentences.
11. Conclude report with a list of things learned as a result of the experiment.

Station | AVIATION HIGH SCHOOL | Exp.# | APPLIED PHYSICS LABORATORY | Team

Name ____________________

PROBLEM:

APPARATUS: REFERENCES:

PROCEDURE:

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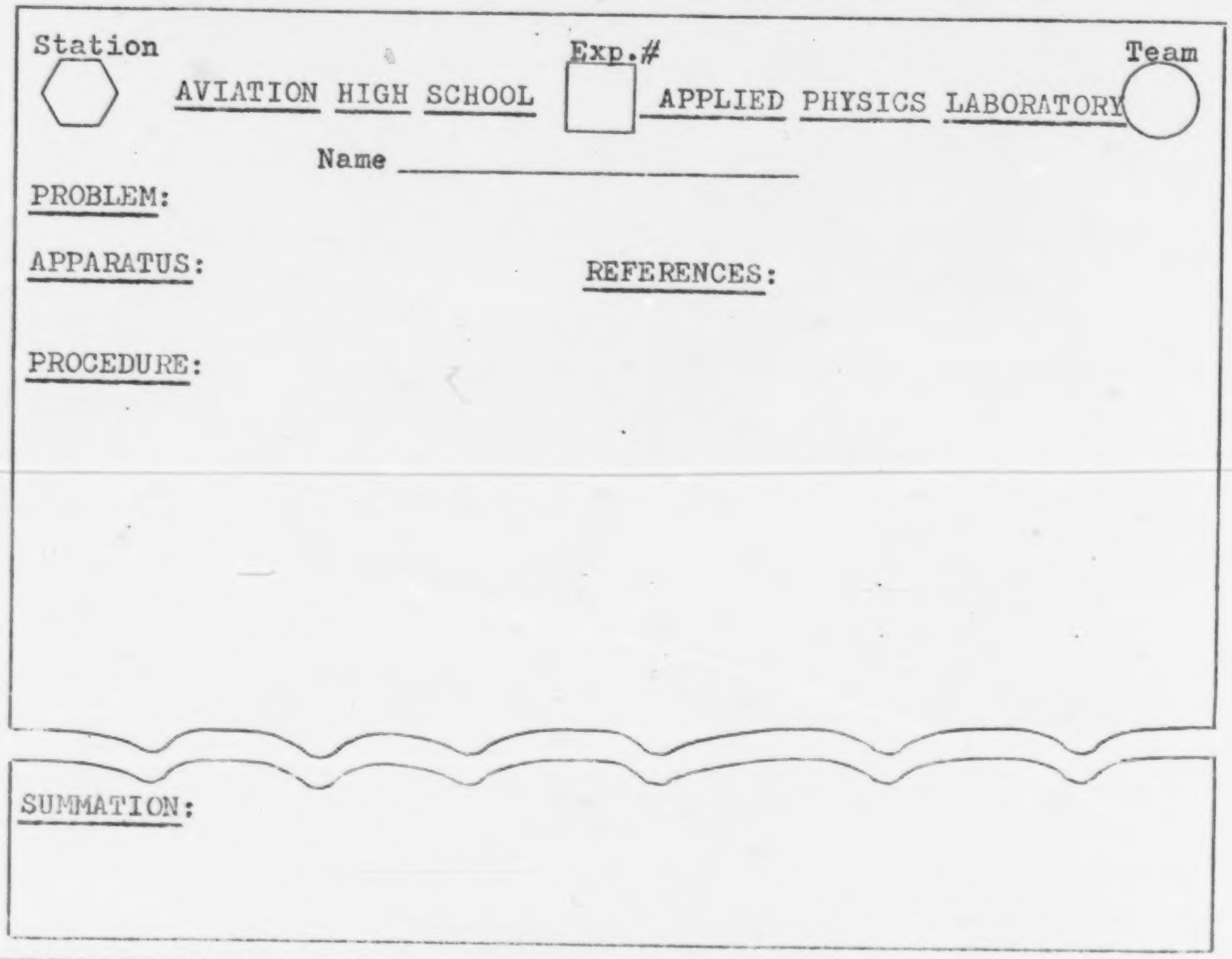


Station ⬡ AVIATION HIGH SCHOOL Exp.# ☐ APPLIED PHYSICS LABORATORY Team ○

Name ____________________________

PROBLEM:

APPARATUS: REFERENCES:

PROCEDURE:

SUMMATION:

Station ⬡ AVIATION HIGH SCHOOL Exp.# 30 APPLIED PHYSICS LABORATORY Team ○

> "Historically as well as logically, mechanics represents the foundation of physics and the prototype for the study of other physical sciences. The concepts which we shall meet in mechanics will appear again and again....as though mechanics provided a frame on which physical science is erected...mechanics is to physics what the skeleton is to the human figure...."
>
> Gerald Holton

PROBLEM: To experimentally determine the velocities, momentums, and kinetic energies of two objects separated by an "explosion."

APPARATUS:

Stop watch
2 momentum carts
2 #6 batteries
2 bumpers
Timer supports
Triple beam balance
2 recording timers & tape
Gm."wt" set
Kg "wts"
4 clip leads
4 clamps
2 clips

REFERENCES:

1. White, Modern College Physics, pp. 125-6
2. Feynman, Lectures on Physics, pp. 101-108
3. Sears & Zemansky, University Physics, pp. 192-4

GATHERING THE DATA:

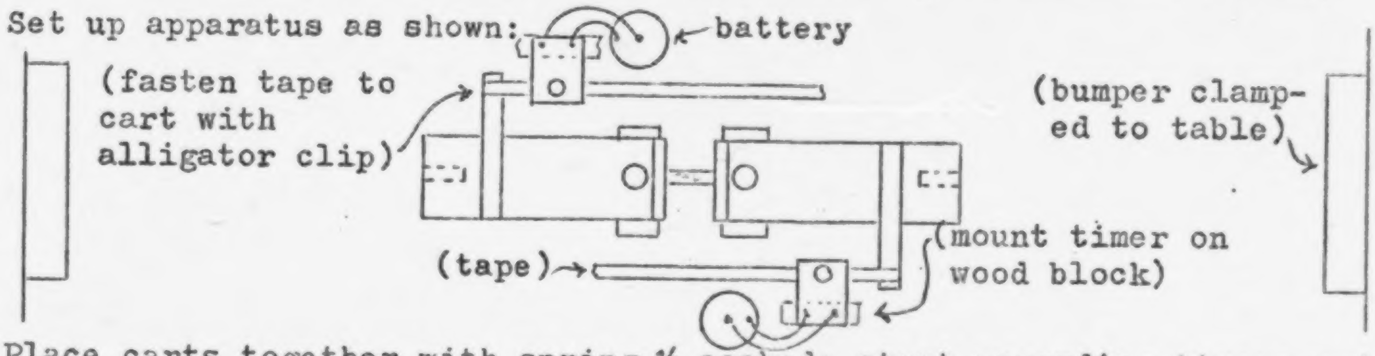
CAUTION: WEAR GOGGLES DURING EXPERIMENT: KEEP AWAY FROM EXPLODER SPRING!

1. Calibrate recorder timer A and recorder timer B.
   a) pull approx. 1 meter of tape through timer during a carefully measured period of time.
   b) count spaces by marking off in groups of 10.
   c) time for one space = $\frac{t \text{ (time for all spaces)}}{\text{number of spaces in time } t}$
   (Note: the timers will probably have different frequencies--do not confuse them)

2. Measure and record mass of each cart.

3. Inspect operation of spring mechanism.
   a) release spring lock on bottom of cart--keep away from face!
   b) press spring release--reload in half cocked position and release.
   --reload in fully cocked position and release.

4. a) Set up apparatus as shown:


battery
(fasten tape to cart with alligator clip)
(bumper clamped to table)
(tape)
(mount timer on wood block)

   b) Place carts together with spring ½ cocked; start recording timers and release "exploder" spring.
   c) Mark off and measure the first ten equal spaces--determine the time for the 10 spaces.
   d) Repeat for fully cocked spring.

5. Repeat step #4 for cart B with mass 2x that of cart A; Cart B with mass 4x that of cart A. Record data in table & complete calculations:

> physical science is erected...mechanics is to physics what the skeleton is to the human figure...."
>
> Gerald Holton

PROBLEM: To experimentally determine the velocities, momentums, and kinetic energies of two objects separated by an "explosion."

APPARATUS:

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- 2 bumpers
- Timer supports
- Triple beam balance
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- Gm "wt" set
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   (Note: the timers will probably have different frequencies--do not confuse them)
2. Measure and record mass of each cart.
3. Inspect operation of spring mechanism.
   a) release spring lock on bottom of cart--keep away from face!
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   --reload in fully cocked position and release.
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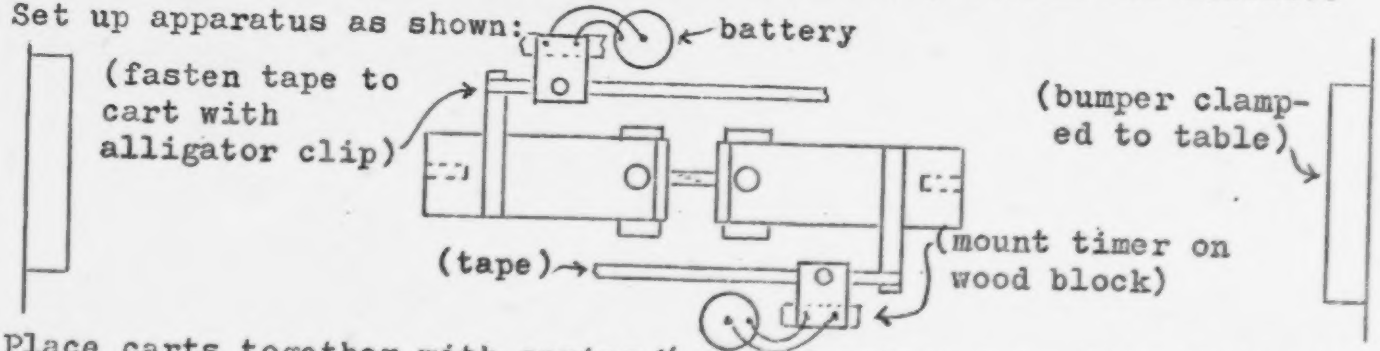
battery
(fasten tape to cart with alligator clip)
(bumper clamped to table)
(tape)
(mount timer on wood block)

   b) Place carts together with spring ½ cocked; start recording timers and release "exploder" spring.
   c) Mark off and measure the first ten equal spaces--determine the time for the 10 spaces.
   d) Repeat for fully cocked spring.
5. Repeat step #4 for cart B with mass 2x that of cart A; Cart B with mass 4x that of cart A. Record data in table & complete calculations:

Spring Half Cocked	10 spaces meters		Total Mass kg		Velocity $v = \frac{s}{t}$		Momentum $p = mv$		Kinetic Energy $\frac{mv^2}{2}$	
	A	B	A	B	A	B	A	B	A	B
equal masses										
2:1 mass ratio										
4:1 mass ratio										

(Make similar table for data when spring fully cocked.)

SUMMATION: 1. For each test compare:
   a) the velocities of cars A & B. Generalize results.
   b) the momentums of cars A & B. Generalize results.
   c) the kinetic energies of cars A & B. Generalize results.
2. Place a large unknown mass on cart B, repeat step #4, and calculate unknown mass. Check.

Station

Exp. #
31

Team

AVIATION HIGH SCHOOL

APPLIED PHYSICS LABORATORY

> "Galileo devised the inclined plane and the little water clock so that he could measure by pulses in the clock the amount of time elapsed during the space-intervals of a falling body....he made crude tables with a tremendous amount of experimental error in them. He had a crude inclined plane with its surface friction and a crude clock with its irregularities.... But though the data was rough he did get the answer to the question about the way bodies fall."
>
> Mortimer Adler

PROBLEM: To experimentally determine the acceleration of gravity:

1. by using a pendulum
2. by using Atwood's machine.

APPARATUS:

Bob
2 cans
Cord
Stopwatch
Metric tape measure
Double pulley assembly
Triple beam balance
2 x 4 pendulum support and arm
gm "wt" set
graph paper
meter stick

REFERENCES:

1. Arons, Development of Concepts of Physics, pp. 147-8
2. Holton, Foundations of Modern Physical Science, pp.78-80
3. White, Modern College Physics, pp. 248-50

GATHERING THE DATA:

1. Design and implement appropriate experiments for determining g.
2. Show all steps, data, and computations.
3. Finished report should enable other scientists to duplicate and verify results.

> He had a crude inclined plane with its surface friction and a crude clock with its irregularities.... But though the data was rough he did get the answer to the question about the way bodies fall."
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GATHERING THE DATA:

1. Design and implement appropriate experiments for determining g.
2. Show all steps, data, and computations.
3. Finished report should enable other scientists to duplicate and verify results.

SUMMATION:

1. Justify procedures.
2. Explain discrepancies in results and suggest how these could be minimized if the experiment were repeated.

Station ⬡ Exp. # 32 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "A truism now widely believed is that science is more genuinely understood by one who is familiar with its historical background and, conversely, that history which fails to include an account of scientific development is but half the story--and perhaps not the better half."
>
> Carl Boyer

PROBLEM: To predict the ideal mechanical advantages of pulley systems and to experimentally check predictions.

APPARATUS:

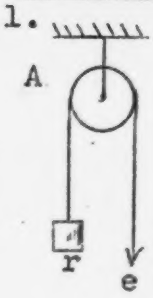
- 6 single pulleys
- 2 double pulleys
- 2 triple pulleys
- 2 quadruple pulleys
- table cross bars
- 2 meter sticks & stands
- gm "wt" set
- rubber bands
- cord

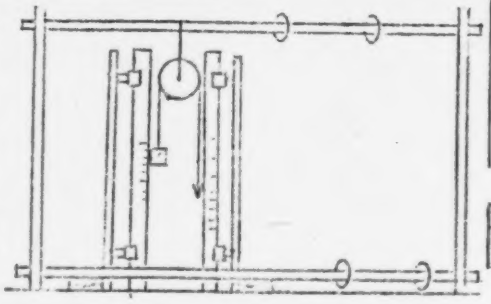
REFERENCES:

1. Dull, Modern Physics, pp. 118-20
2. Rogers, Physics for the Inquiring Mind, pp. 375-7

GATHERING THE DATA:

1.





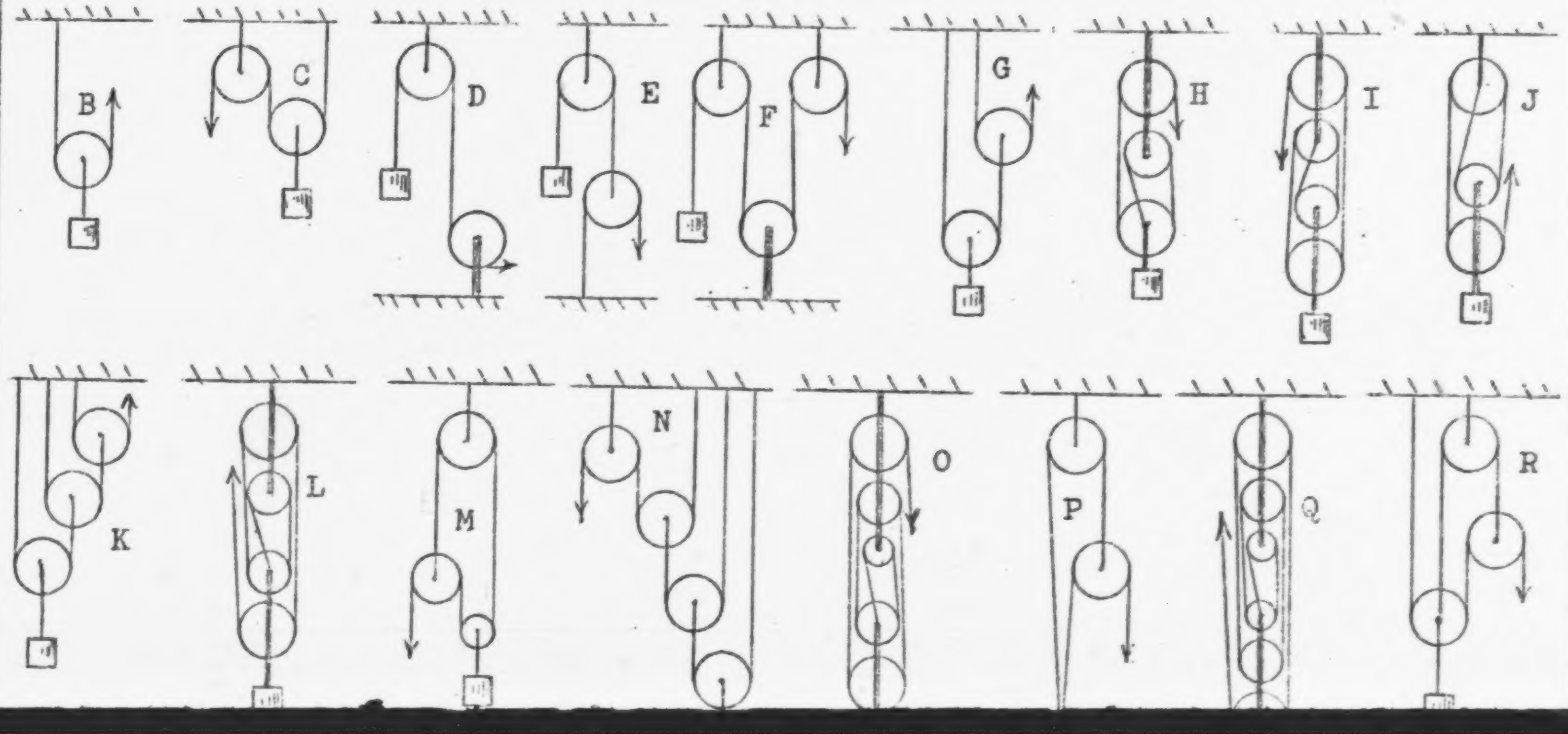
Pulley System	Predicted IMA	e (cm)	r (cm)	Experimental IMA
A				
B				
R				

a) predict IMA of pulley system A

b) hook-up system & move effort a convenient distance & then measure the distance r (load) moves.

c) calculate IMA = $\frac{\text{e distance}}{\text{r distance}}$ (record data in table)

2. Repeat step #1 for the following pulley systems:



better half."

Carl Boyer

PROBLEM: To predict the ideal mechanical advantages of pulley systems and to experimentally check predictions.

APPARATUS:

6 single pulleys
2 double pulleys
2 triple pulleys
2 quadruple pulleys
table cross bars
2 meter sticks & stands

gm "wt" set
rubber bands
cord

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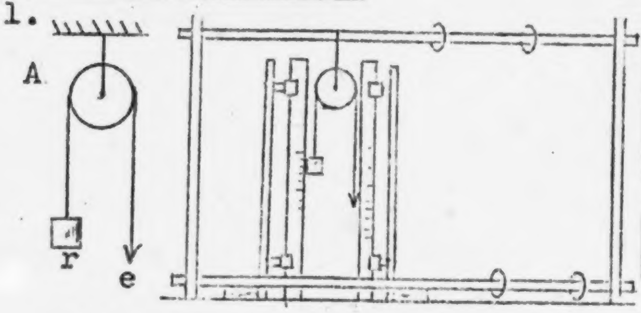
GATHERING THE DATA:

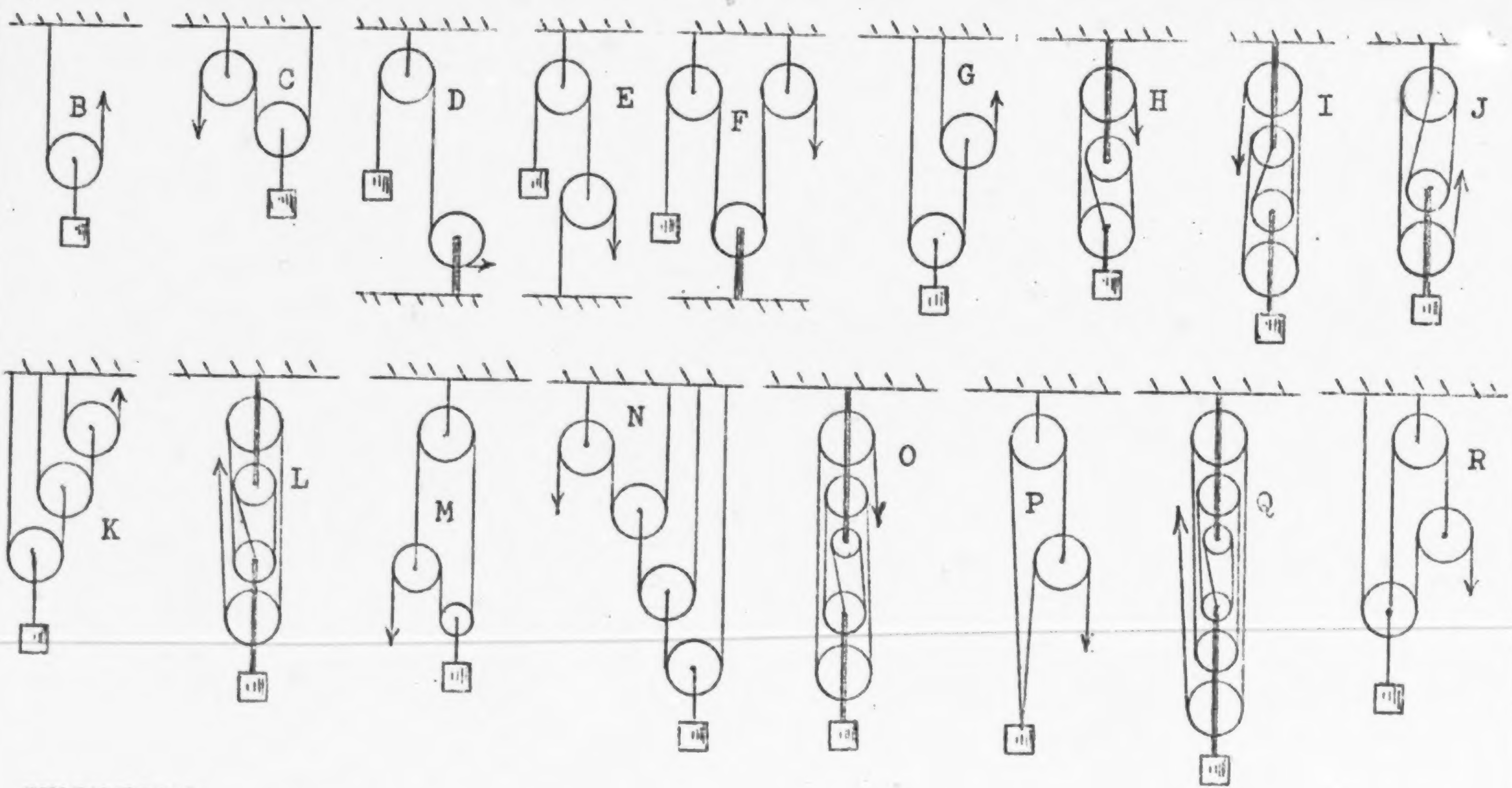
1.



Pulley System	Predicted IMA	e (cm)	r (cm)	Experimental IMA
A				
B				
R				

a) predict IMA of pulley system A
b) hook-up system & move effort a convenient distance & then measure the distance r (load) moves.
c) calculate IMA = $\frac{\text{e distance}}{\text{r distance}}$ (record data in table)

2. Repeat step #1 for the following pulley systems:



SUMMATION:

1. State the general rule usually used to determine the ideal mechanical advantage of a pulley system.
2. Does the rule hold for all the pulley systems tested? If not, for which does it fail? Explain.
3. Describe a method which works for all pulley systems.
4. Which, if any, pulley systems were especially frustrating? Describe difficulties.
5. With available equipment, design & hook-up a pulley system with large IMA.
6. "The human body does not contain any pulley systems." Critically appraise.

Station

Exp. # 33

AVIATION HIGH SCHOOL

APPLIED PHYSICS LABORATORY

Team

> "In nature we never will see anything isolated but everything in connection with something else which is before it, beside it, under it, and over it."
>
> Johann Goethe

PROBLEM: To measure coefficients of friction (Part I)

APPARATUS:

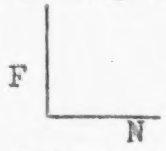
Wood board
Formica board
Masonite board
Glass on board
Level
Cord
Graph paper
250gm spring balance
Hooked "wts." 0-1000gm
Slotted "wts." 0-1000gm
Iron stand & arm
3 wood blocks
Formica block

REFERENCES:

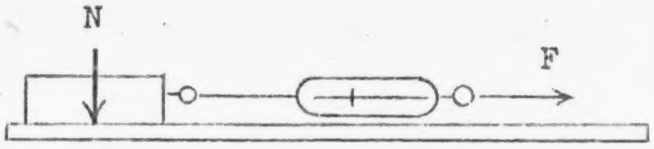
1. Halliday & Resnick, Physics, pp. 95-6
2. Arons, Development of Concepts of Physics, pp. 152-6

GATHERING THE DATA:

1. Method #1
   a) place 100gm wood block with large face on leveled wood board
   b) pull block at constant speed with spring balance & note "gm" force required--record in table.
   c) repeat step #1b with loads successively increasing in 100gm steps to 500gm
   d) plot graph



   e) calculate coefficient of friction

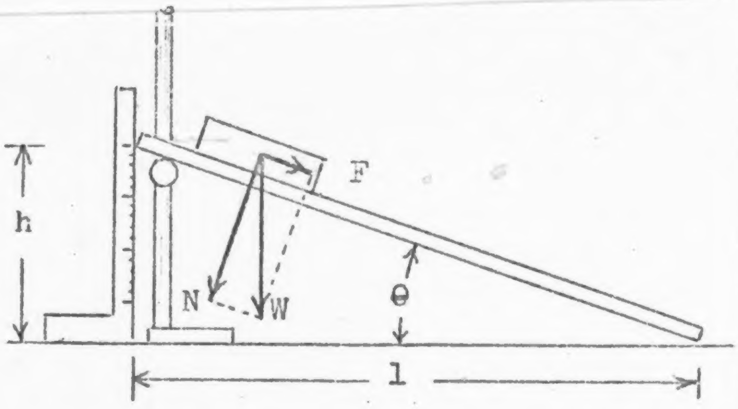


Total load N gms	Force F gms	$\mu = \frac{F}{N}$

2. Method #2
   a) place wood block on wood inclined plane
   b) adjust inclined plane angle until slight push causes wood block to slide down inclined plane at constant speed
   c) measure h & l & record in table
   d) compute coefficient of friction:

$$\mu = \frac{h}{l}$$

   e) repeat previous steps for total loads of 300, 600, & 1000 gms



3. After completing summation, measure the coefficients of friction of all the combinations of materials supplied.
   --use methods #1 and #2 but for only one load in each case

Materials	$\mu = \frac{F}{N}$	$\mu = \frac{h}{l}$
wood on wood		
wood on glass		
formica on glass		

SUMMATION:

PROBLEM: To measure coefficients of friction (Part I)

APPARATUS:

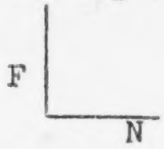
Wood board	250gm spring balance
Formica board	Hooked "wts." 0-1000gm
Masonite board	Slotted "wts." 0-1000gm
Glass on board	Iron stand & arm
Level	3 wood blocks
Cord	Formica block
Graph paper	

REFERENCES:

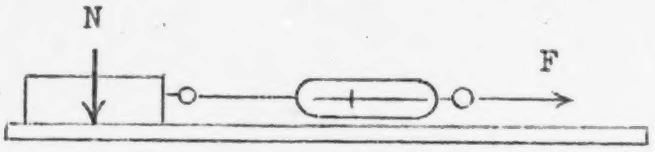
1. Halliday & Resnick, Physics, pp. 95-6
2. Arons, Development of Concepts of Physics, pp. 152-6

GATHERING THE DATA:

1. Method #1
   a) place 100gm wood block with large face on leveled wood board
   b) pull block at constant speed with spring balance & note "gm" force required--record in table.
   c) repeat step #1b with loads successively increasing in 100gm steps to 500gm
   d) plot graph



   e) calculate coefficient of friction

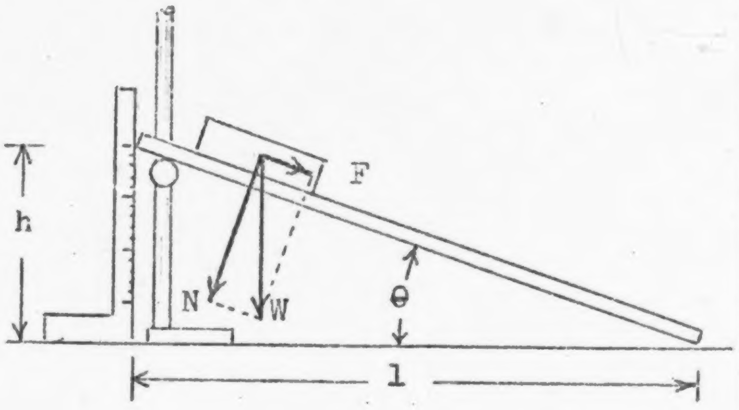


Total load N gms	Force F gms	$\mu = \frac{F}{N}$

2. Method #2
   a) place wood block on wood inclined plane
   b) adjust inclined plane angle until slight push causes wood block to slide down inclined plane at constant speed
   c) measure h & l & record in table
   d) compute coefficient of friction:

$$\mu = \frac{h}{l}$$

   e) repeat previous steps for total loads of 300, 600, & 1000 gms



3. After completing summation, measure the coefficients of friction of all the combinations of materials supplied.
   --use methods #1 and #2 but for only one load in each case

Materials	$\mu = \frac{F}{N}$	$\mu = \frac{h}{l}$
wood on wood		
wood on glass		
formica on glass		

SUMMATION:

1. For method #1, what relationship does the graph indicate exists between force F and normal force N? What is the constant of proportionality called?
2. Derive equation: $\mu = \frac{h}{l}$ (hint - use trigonometric relations)
3. How does load affect: a) the coefficient of friction?
   b) the force of friction?
4. "Coefficient of friction is independent of contact area"
   Devise and implement an experiment which tests this statement.

Station ⬡ AVIATION HIGH SCHOOL Exp.# 34 APPLIED PHYSICS LABORATORY Team ○

> "Mechanics is the paradise of the mathematical sciences because by means of it one comes to the fruits of mathematics."
>
> Leonardo da Vinci

> "A research problem is not solved by apparatus, it is solved in a man's head... The laboratory is the means by which it is possible to do the solving after the man has the idea clarified in his mind."
>
> Chas. F. Kettering

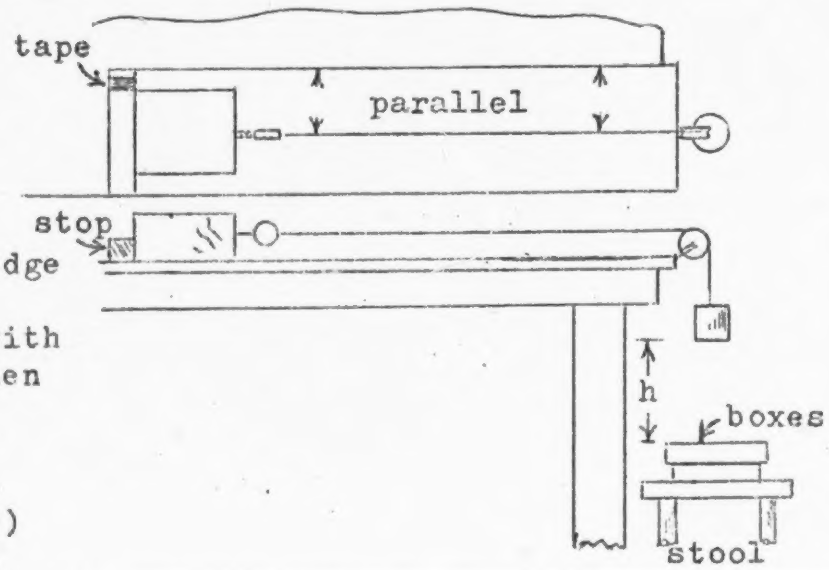
PROBLEM: To measure coefficients of friction by a method which avoids the necessity for moving the objects tested at constant speed.

APPARATUS:

Wood board
Masonite board
Formica board
Glass on board
Hook-wts. 10-500 gm
Slot-wts. 10-500 gm
Level
Cord
Meter stick

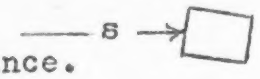
REFERENCES:

1. Eagleson, Am. Journal of Physics-- Vol. 13 p. 43



GATHERING THE DATA:

1. Method #3
   - a) attach 100 gm wood block to 100 gm wt.
   - b) level wooden board & set at edge of lab. table as shown.
   - c) line up block against stop, with cord parallel to sides of wooden board (use tape indicator for easy repetition)
   - d) adjust distance h to approximately (but carefully measured) 25 cm
   - e) release block and measure total distance traveled s
     - -use the mean of several trials
     - -for a particular trial, if block tilts, use mean distance.

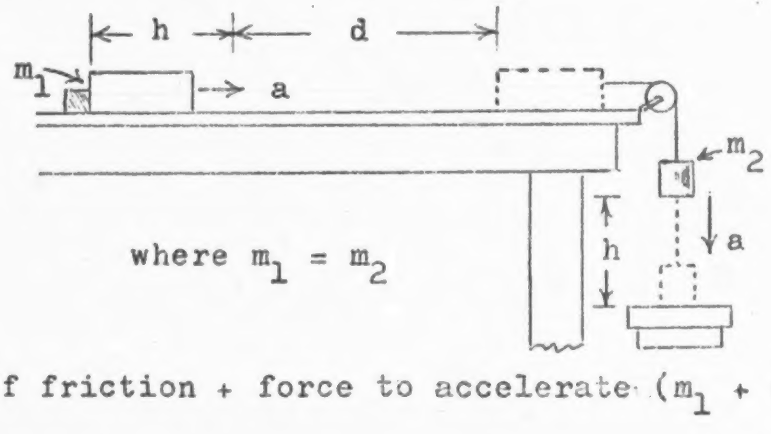


   - f) calculate coefficient of friction $\mu = \frac{h}{h+2d}$ where ($d = s-h$)

2. After completing summation, repeat method #3 to determine the coefficients of friction of other combinations of materials.

SUMMATION:

1. Derive equation $\mu = \frac{h}{h+2d}$
   - a) let:



   - b) Hint: Equate forces
     Force exerted by m_2 = force of friction + force to accelerate $(m_1 + m_2)$
     Note $m_1 = m_2$ (by design)

> "A research problem is not solved by apparatus, it is solved in a man's head... The laboratory is the means by which it is possible to do the solving after the man has the idea clarified in his mind."
>
> Chas. F. Kettering

PROBLEM: To measure coefficients of friction by a method which avoids the necessity for moving the objects tested at constant speed.

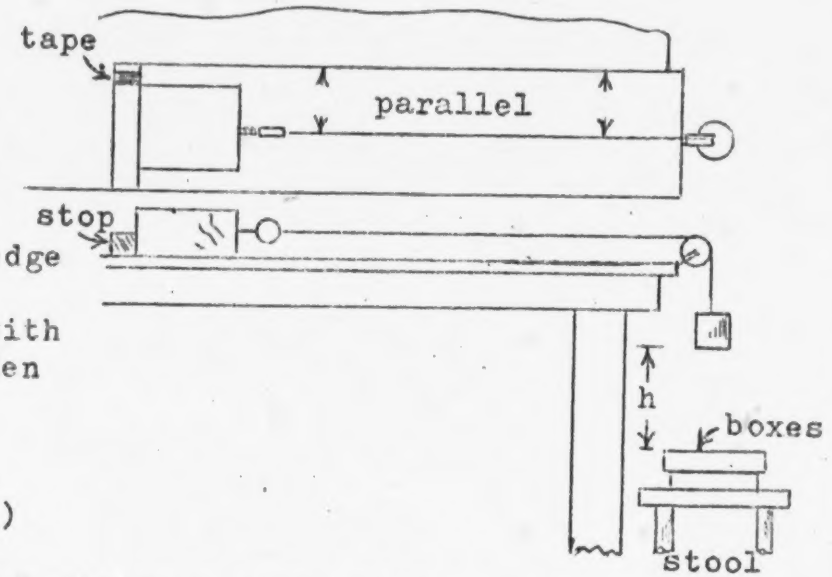
APPARATUS:

Wood board
Masonite board
Formica board
Glass on board
Hook-wts. 10-500 gm
Slot-wts. 10-500 gm
Level
Cord
Meter stick

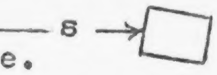
REFERENCES:

1. Eagleson, Am. Journal of Physics-- Vol. 13 p. 43

GATHERING THE DATA:



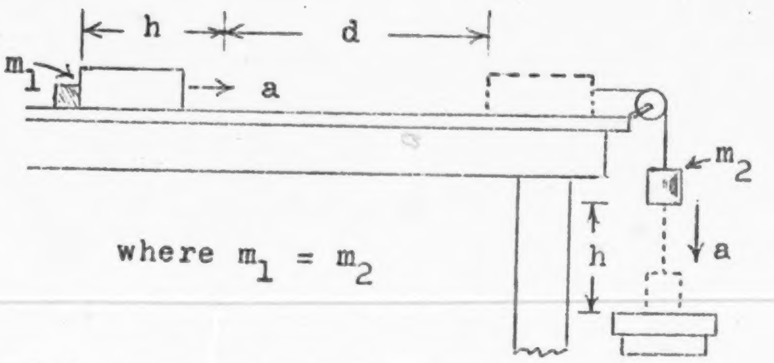
1. Method #3
   - a) attach 100 gm wood block to 100 gm wt.
   - b) level wooden board & set at edge of lab. table as shown.
   - c) line up block against stop, with cord parallel to sides of wooden board (use tape indicator for easy repetition)
   - d) adjust distance h to approximately (but carefully measured) 25 cm
   - e) release block and measure total distance traveled s
     - -use the mean of several trials
     - -for a particular trial, if block tilts, use mean distance.
   - f) calculate coefficient of friction $\mu = \frac{h}{h+2d}$ where $(d = s-h)$



2. After completing summation, repeat method #3 to determine the coefficients of friction of other combinations of materials.

SUMMATION:

1. Derive equation $\mu = \frac{h}{h + 2d}$
   - a) let:



   - b) Hint: Equate forces
     Force exerted by m_2 = force of friction + force to accelerate $(m_1 + m_2)$
     Note $m_1 = m_2$ (by design)
   - c) Hint: Solve for a.
   - d) Hint: Equate energies
     Potential energy of m_2 (at start) = total work against friction for distance (h+d) + kinetic energy of m_2 (in terms of a) (just before m_2 stops)
   - e) Hint: Substitute value of a from step c in step d & solve for μ
2. Justify hints b and d.

Station

AVIATION HIGH SCHOOL

Exp.# 35

APPLIED PHYSICS LABORATORY

Team

> "Much of the significance of accumulated knowledge lies in an understanding of the process by which it was accumulated."
>
> James B. Conant

> "The history of an exact science does not deviate markedly from its structure as developed logically."
>
> Max Planck

PROBLEM: To determine the mechanical advantages and efficiencies of machines.

APPARATUS:

2 nt. scales	Jack
1 single pulley	Cord
2 double pulleys	Gm "wt" set
2 triple pulleys	25 kg "wts"
2 quadruple pulleys	Iron stand
Table cross bar	Chain hoist
Worm & worm wheel	Gear train

REFERENCES:

1. Dull, Modern Physics, pp. 124-7
2. Taffel, Visualized Physics, pp. 96-108
3. Rogers, Physics for the Inquiring Mind, pp. 373-6

GATHERING THE DATA:

1. Place appropriate load (measured in newtons) on each of the following pulley systems and determine:

a) IMA $= \frac{E_d}{R_d}$

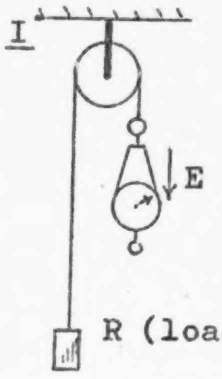
b) AMA $= \frac{R}{E}$

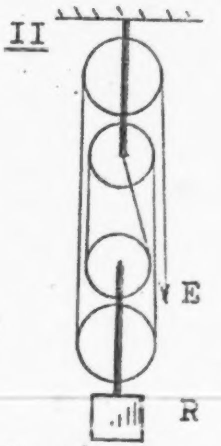
c) Eff. $= \frac{\text{Workout}}{\text{Workin}}$

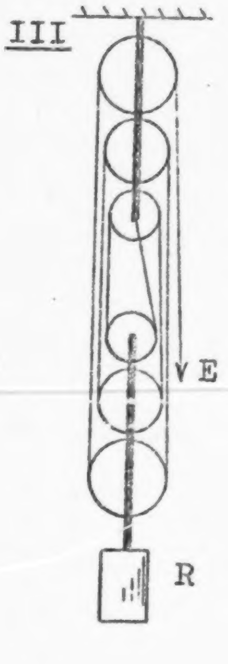
d) Eff. $= \frac{\text{AMA}}{\text{IMA}}$

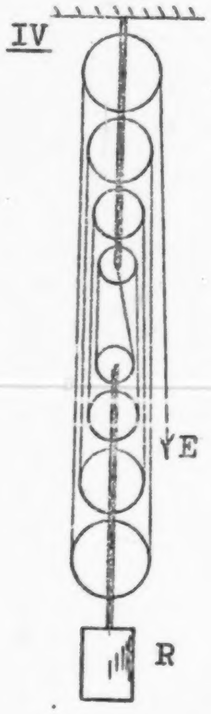
e) Eff. $= \frac{E_+ + E_-}{2E_+}$

(where E_+ is the downward effort at constant velocity & E_- is the upward effort at constant velocity as load R is allowed to move downward)





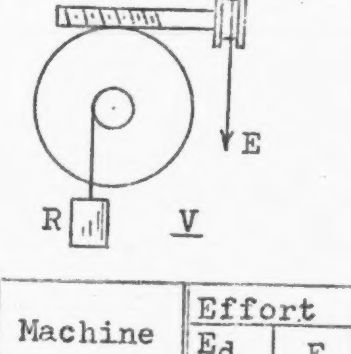




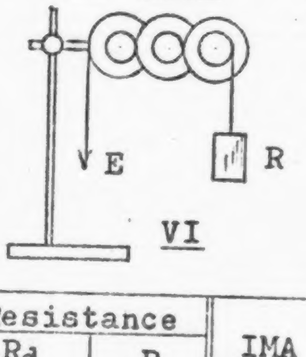
Note: --measure E when it is moving at constant velocity.
--include newton scale weight in E value.

2. Repeat step #1 for the following machines:

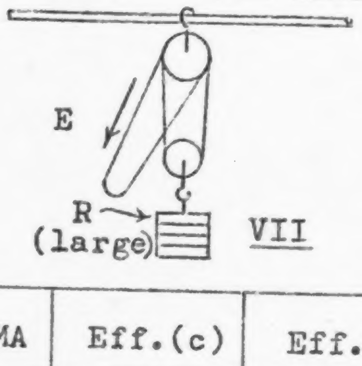
Worm & Worm wheel



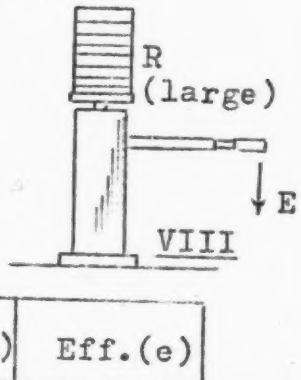
Gear Train



Differential Chain Hoist



Jack



Machine	Effort		Resistance		IMA	AMA	Eff.(c)	Eff.(d)	Eff.(e)
	E_d	E	R_d	R					
I									
II									

> "The history of an exact science does not deviate markedly from its structure as developed logically."
>
> Max Planck

PROBLEM: To determine the mechanical advantages and efficiencies of machines.

APPARATUS:

2 nt. scales	Jack
1 single pulley	Cord
2 double pulleys	Gm "wt" set
2 triple pulleys	25 kg "wts"
2 quadruple pulleys	Iron stand
Table cross bar	Chain hoist
Worm & worm wheel	Gear train

REFERENCES:

1. Dull, Modern Physics, pp. 124-7
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GATHERING THE DATA:

1. Place appropriate load (measured in newtons) on each of the following pulley systems and determine:

a) IMA $= \frac{E_d}{R_d}$

b) AMA $= \frac{R}{E}$

c) Eff. $= \frac{\text{Workout}}{\text{Workin}}$

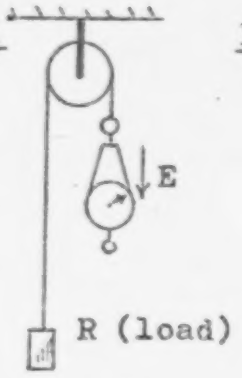
d) Eff. $= \frac{\text{AMA}}{\text{IMA}}$

e) Eff. $= \frac{E_+ + E_-}{2E_+}$

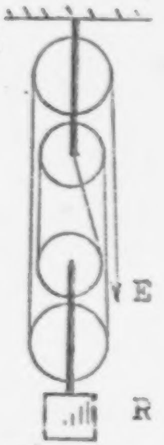
(where E_+ is the downward effort at constant velocity & E_- is the upward effort at constant velocity as load R is allowed to move downward)

Note: --measure E when it is moving at constant velocity.
--include newton scale weight in E value.

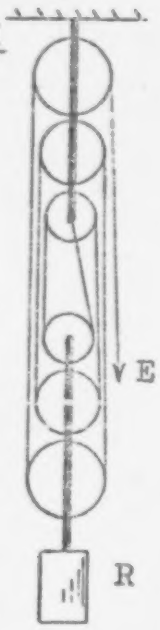
I



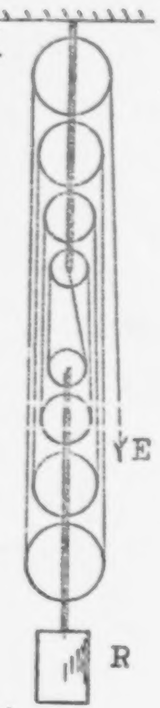
II



III

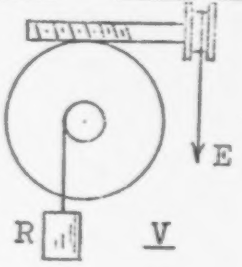


IV



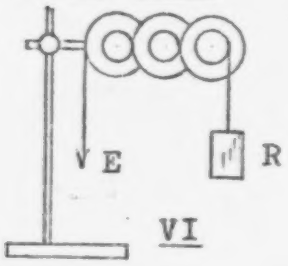
2. Repeat step #1 for the following machines:

Worm & Worm wheel



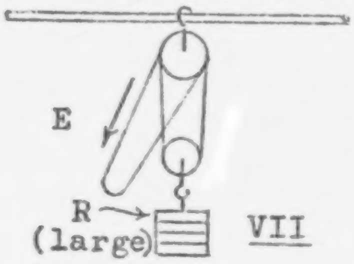
V

Gear Train



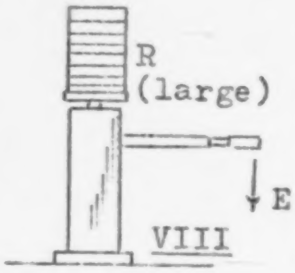
VI

Differential Chain Hoist



VII

Jack



VIII

Machine	Effort		Resistance		IMA	AMA	Eff.(c)	Eff.(d)	Eff.(e)
	E_d	E	R_d	R					
I									
II									
VIII									

SUMMATION:

1. Justify: a) Eff. $= \frac{\text{AMA}}{\text{IMA}}$ b) Eff. $= \frac{E_+ + E_-}{2E_+}$
2. Why was it necessary to move E with constant velocity when taking readings?
3. Describe an easy way of increasing the jack's mechanical advantage within reasonable limits.
4. Why isn't Eff. $= \frac{E_+ + E_-}{2E_+}$ always applicable?
5. Compare the methods for determining machine efficiency.

Station

AVIATION HIGH SCHOOL

Exp. # 36

APPLIED PHYSICS LABORATORY

Team

> "I never try to dissuade a man from trying an experiment. If he does not find what he wants he may find out something else."
>
> Clerk Maxwell
>
> "The book of Nature is a fine large tapestry rolled up which we are not able to see all at once."
>
> Robert Boyle

PROBLEM: To measure and calculate pressures and to check the relationship between air pressure and volume.

APPARATUS:

Pressure gauge
Plastic tubing
Hand pump
Iron stand and clamps
Weights, stirrup, and stand
Scale
Barometer

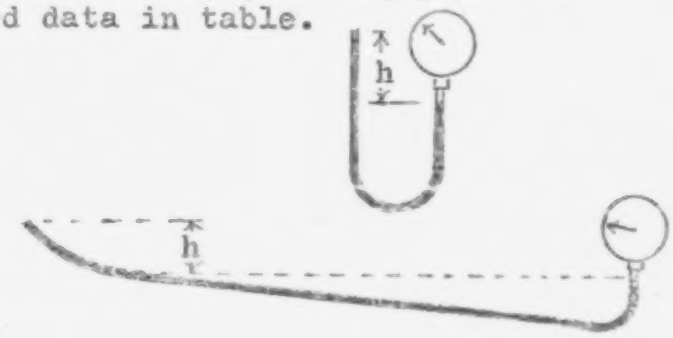
REFERENCES:

1. Gamow, Physics Fund. and Frontiers, pp. 26-30
2. Beiser, The Science of Physics, pp. 150-52
3. Stollberg & Hill, Physics, pp. 203-6
4. Sears & Zemansky, University Physics, pp. 283-5
5. Halliday & Resnick, Physics, pp. 364-67

GATHERING THE DATA:

1. Check water pressure vs. head.
   a) Fill plastic tubing completely with water using sink faucet--avoid bubbles--keep water in tubing by holding both ends of tubing at same height from floor.
   b) Fasten one end of tubing to pressure gauge.
   c) Mount pressure gauge at bottom of lab. table with bolts.
   d) Gradually raise free end of tubing in 0.5' steps, noting pressure gauge reading at each step, and record data in table.

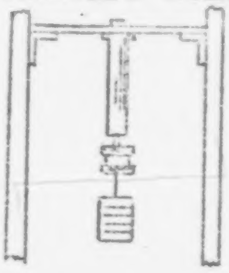
Head h (ft.)	Gauge Pressure (psi)
0	
0.5	
10	



e) Plot: gauge psi vs. h (ft)

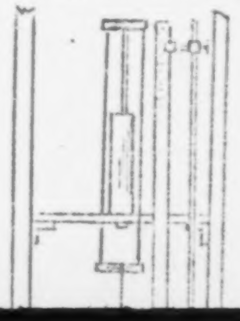
f) Repeat d with tubing extended as shown

2. Measure atmospheric pressure using hand pump.



   a) Determine bore & cross sectional area of pump cylinder.
   b) Push piston in as far as it will go and find wt.:
      i) W' req. to make piston move downward at constant speed with intake valve open.
      ii) W req. to make piston fall full length with intake valve sealed.
   c) Calculate atmospheric pressure (let F = W - W')

3. Relate air volume and pressure using hand pump.



   a) Withdraw piston completely & add wt. w' until piston moves downward at constant speed with exhaust valve open.
   b) Withdraw piston completely & seal exhaust valve with weight w' in place.
   c) Record integral reading on yd. stick & gradually load piston in equal 0.5 lb. steps while recording compression in inches.

Load	Comp. In.	psi	abs.psi	Comp. Air Vol

d) Plot:

> "The book of Nature is a fine large tapestry rolled up which we are not able to see all at once."
>
> Robert Boyle

PROBLEM: To measure and calculate pressures and to check the relationship between air pressure and volume.

APPARATUS:

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GATHERING THE DATA:

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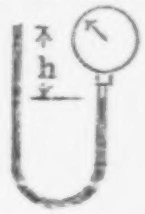
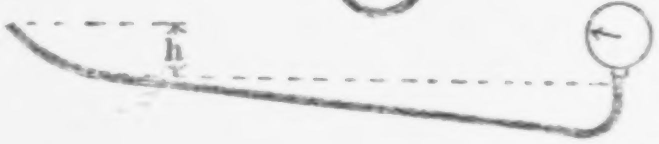
Head h (ft.)	Gauge Pressure (psi)
0	
0.5	
10	



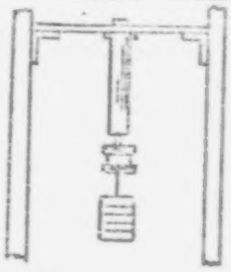
   e) Plot: gauge psi

h (ft)

   f) Repeat d with tubing extended as shown

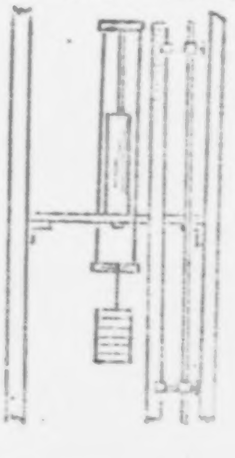


2. Measure atmospheric pressure using hand pump.



   a) Determine bore & cross sectional area of pump cylinder.
   b) Push piston in as far as it will go and find wt.:
      i) W' req. to make piston move downward at constant speed with intake valve open.
      ii) W req. to make piston fall full length with intake valve sealed.
   c) Calculate atmospheric pressure (let F = W - W')

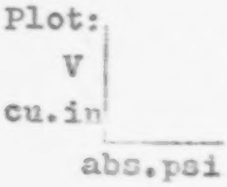
3. Relate air volume and pressure using hand pump.



   a) Withdraw piston completely & add wt. w' until piston moves downward at constant speed with exhaust valve open.
   b) Withdraw piston completely & seal exhaust valve with weight w' in place.
   c) Record integral reading on yd. stick & gradually load piston in equal 0.5 lb. steps while recording compression in inches.

Load	Comp. In.	psi	abs.psi	Comp. Air Vol
0.5				
etc.				

   d) Plot:



SUMMATION:

1. According to step #1, what is the:
   a) relation between water head and pressure?
   b) head required to produce 1 psi with water? (use max. head data)
2. Explain why pump piston does not fall down immediately in step #2 when it is first loaded.
3. Explain calculations for: a) pressure b) abs. pressure c) compressed air volume
4. What is the relationship between absolute pressure and volume?

Station ⬡ AVIATION HIGH SCHOOL Exp.# 37 APPLIED PHYSICS LABORATORY Team ○

> "...all the pictures which science now draws of nature, and which alone seem capable of according with observational facts are mathematical pictures." -
>
> James Jeans

> "The fate of every theory of the universe is decided by a numerical test. Does the sum come out right? I am not sure that the mathematician understands this world of ours better than the poet and mystic. Perhaps he is only better at sums."
>
> Arthur Eddington

PROBLEM: To experimentally determine the relationship between air pressure and volume.

APPARATUS:

Welch mercury columns:
- -air pump form
- -plunger form

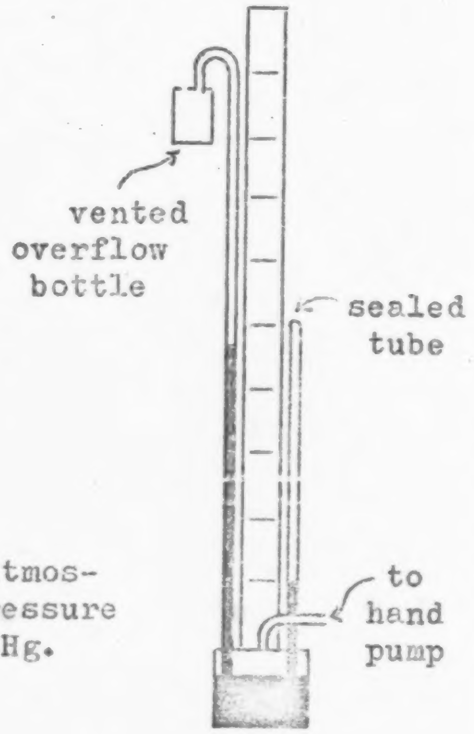
Hand pump and hose
Table clamps
Barometer

REFERENCES:

1. Semat, Fundamentals of Physics, pp. 176-7
2. Arons, Development of Concepts of Physics, pp. 717-9
3. Beiser, The Science of Physics, pp. 150-52

GATHERING THE DATA:

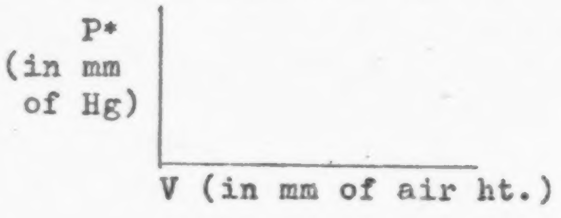
1. a) Use hand pump to force mercury up the vented and sealed tubes until mercury is at top of vented tube.
   --use wire to remove air bubbles if necessary.
   b) Note mercury height in both tubes, subtract, and record as mercury head in millimeters.*
   c) Associate mercury head with height of air column under pressure.
   d) Decrease height of mercury column in vented tube in successive 5cm. steps, repeating steps b & c, and recording data--carefully release air via valve to secure desired mercury height.



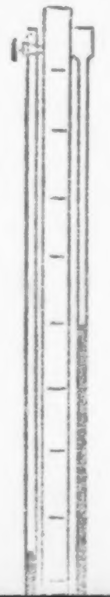
mm of Hg	Air Vol. (in mm of ht.)

*include atmospheric pressure in mm of Hg.

e) Plot graph:



2. a) Open valve and turn plunger until mercury in both columns at bottom of meter stick.
   b) Close valve and turn plunger until mercury rises 5cm. in the vented column--check that valve does not leak.
   c) Note mercury height in both tubes, subtract, and record as mercury head in millimeters.*
   d) Associate mercury head with height of air column under pressure.
   e) Increase height of mercury in vented tube in successive 5cm. steps, repeating steps c & d and recording data.



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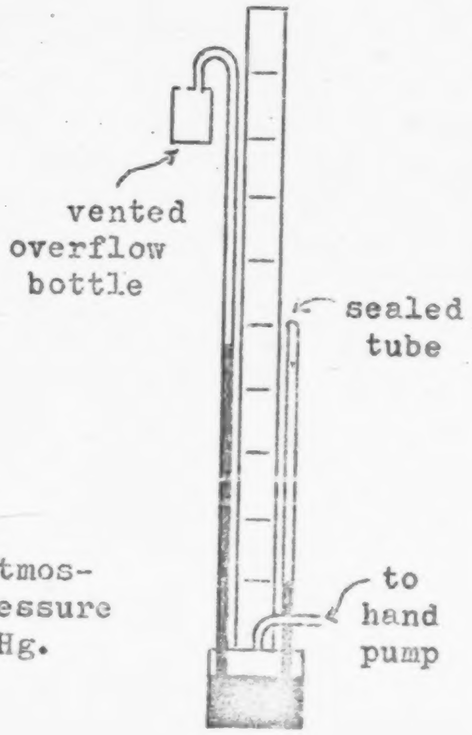
GATHERING THE DATA:

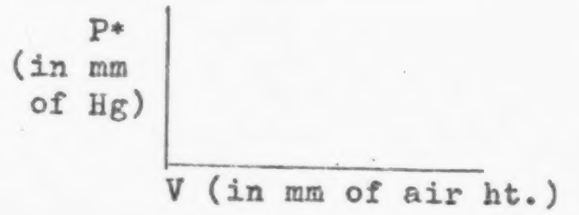


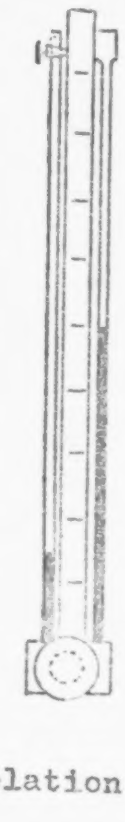
1. a) Use hand pump to force mercury up the vented and sealed tubes until mercury is at top of vented tube.
   --use wire to remove air bubbles if necessary.
   b) Note mercury height in both tubes, subtract, and record as mercury head in millimeters.*
   c) Associate mercury head with height of air column under pressure.
   d) Decrease height of mercury column in vented tube in successive 5cm. steps, repeating steps b & c, and recording data--carefully release air via valve to secure desired mercury height.

mm of Hg	Air Vol. (in mm of ht.)

*include atmospheric pressure in mm of Hg.

   e) Plot graph:





2. a) Open valve and turn plunger until mercury in both columns at bottom of meter stick.
   b) Close valve and turn plunger until mercury rises 5cm. in the vented column--check that valve does not leak.
   c) Note mercury height in both tubes, subtract, and record as mercury head in millimeters.*
   d) Associate mercury head with height of air column under pressure.
   e) Increase height of mercury in vented tube in successive 5cm. steps, repeating steps c & d and recording data.
   f) Plot graph P vs. V

SUMMATION:

1. According to the graphs in steps #1 and #2 above, what is the relation between air pressure and volume?
2. Using the physical data, show mathematically that a simple relationship holds.
3. Graph the data in a way which demonstrates the relationship in a simpler fashion.
4. Contrast the advantages and disadvantages of the two devices used to gather the data.

Station

Exp.# 38

AVIATION HIGH SCHOOL **APPLIED PHYSICS LABORATORY**

Team

> "Fortunately, just as diamonds are often found in the most disagreeable surroundings, so some of the brightest scientific ideas can be found in the study of the motion of bombs and shells."
>
> Morris Kline

PROBLEM: To experimentally examine projectile paths.

APPARATUS:

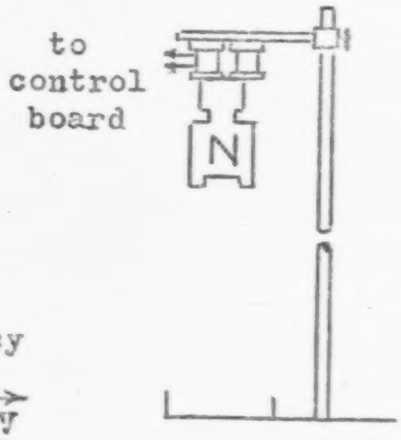
Electromagnet
Air Cannon
Gunnery Range
Control Board & Gauge
White & carbon paper
Nylon cannon balls
Triple beam balance
Goggles
Square
Spring gun
Protractor
Target
Meter tape
Leads

REFERENCES:

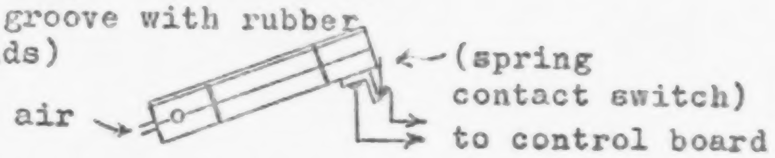
1. Rogers, Physics for the Inquiring Mind, pp. 48-51
2. Halliday & Resnick, Physics, pp. 50-55
3. Sears & Zemansky, University Physics, pp. 129-35
4. White, Modern College Physics, pp. 94-99

GATHERING THE DATA: WEAR SAFETY GOGGLES !!

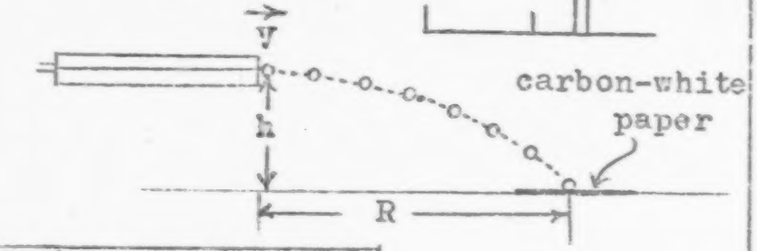
1. Use spring gun to simultaneously release one ball downward and another horizontally and note the order in which they hit the floor.
2. a) Connect electric and pneumatic lines to the control board, "cannon", and target electromagnet.
   b) Mount target approx. 3 meters above the floor.
   c) Aim cannon at target.



(use sighting tube held in groove with rubber bands)



   d) fire & observe--repeat to demonstrate consistency
   e) disconnect electromagnet wires
3. Determine muzzle velocity V
   a) set cannon for horizontal firing --use level
   b) fire projectile & measure height h, range R, and air pressure P.
   c) use average of 10 tests for R & P.
   d) record data in table.

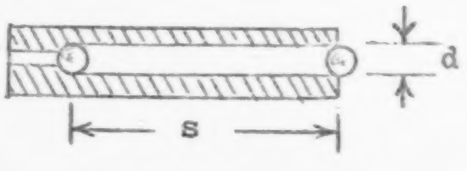


Test	P(lb/sq.in.)	R	h
1			

   e) calculate V: $$\left.\begin{array}{l} R = Vt \\ h = \dfrac{gt^2}{2} \end{array}\right] \longrightarrow V = \frac{R}{\sqrt{\dfrac{2h}{g}}}$$

4. Calculate air pressure using data of step #3

$$\left.\begin{array}{l} 2as = V^2 \\ F = ma \\ P = \dfrac{F}{\pi d^2/4} \end{array}\right] \longrightarrow P = \frac{mgR^2}{hs\pi d^2}$$



PROBLEM: To experimentally examine projectile paths.

APPARATUS:

- Electromagnet
- Air Cannon
- Gunnery Range
- Control Board & Gauge
- White & carbon paper
- Nylon cannon balls
- Triple beam balance
- Goggles
- Square
- Spring gun
- Protractor
- Target
- Meter tape
- Leads

REFERENCES:

1. Rogers, Physics for the Inquiring Mind, pp. 48-51
2. Halliday & Resnick, Physics, pp. 50-55
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4. White, Modern College Physics, pp. 94-99

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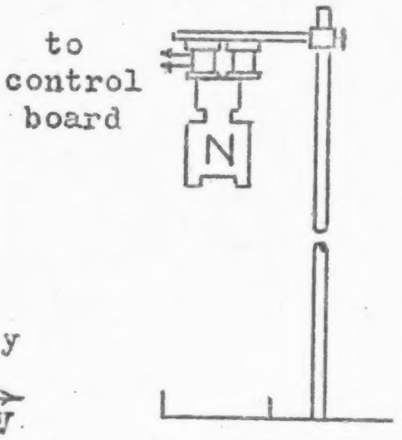
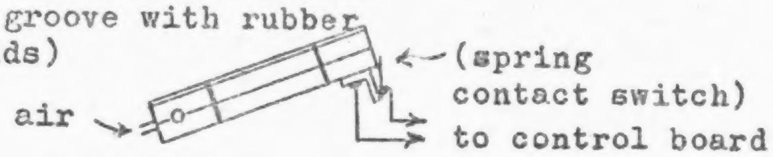
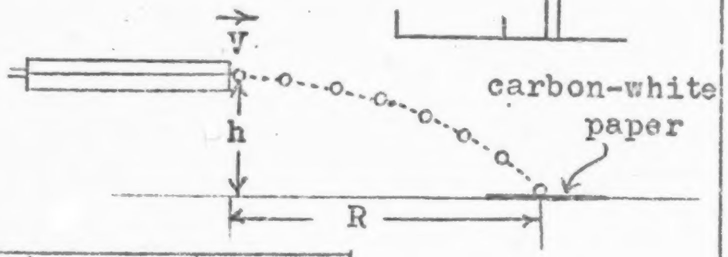
2. a) Connect electric and pneumatic lines to the control board, "cannon", and target electromagnet.
   b) Mount target approx. 3 meters above the floor.
   c) Aim cannon at target.



(use sighting tube held in groove with rubber bands)



   d) fire & observe--repeat to demonstrate consistency
   e) disconnect electromagnet wires
3. Determine muzzle velocity V
   a) set cannon for horizontal firing --use level
   b) fire projectile & measure height h, range R, and air pressure P.
   c) use average of 10 tests for R & P.
   d) record data in table.



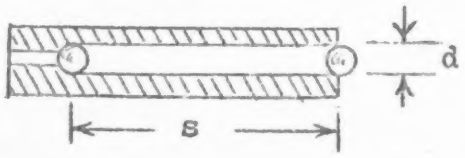
Test	P(lb/sq.in.)	R	h
1			

   e) calculate V:

$$\left.\begin{array}{l} R = Vt \\ h = \dfrac{gt^2}{2} \end{array}\right] \longrightarrow V = \frac{R}{\sqrt{\dfrac{2h}{g}}}$$

4. Calculate air pressure using data of step #3

$$\left.\begin{array}{l} 2as = V^2 \\ F = ma \\ P = \dfrac{F}{\pi d^2/4} \end{array}\right] \longrightarrow P = \frac{mgR^2}{hs\pi d^2}$$



SUMMATION:

1. Draw conclusion regarding horizontal and vertical motions based on observation of spring gun.
2. Explain why the projectile aimed directly at the target held by electromagnet hits the falling target despite variations in muzzle velocity.
3. Explain the mathematics and physics of steps #3 and #4 of GATHERING THE DATA.
4. Contrast measured and calculated pressures--explain discrepancies.
5. Justify: "At 45° angle of elevation, range is maximum."

Station ⬡ AVIATION HIGH SCHOOL Exp. # 39 APPLIED PHYSICS LABORATORY Team ○

> "If this experiment were performed on the moon or Mars, with the ball rolling down the same incline over the same course, it would produce the same curve, not just a similar curve ... if he (the experimenter), correctly diagnoses this interesting conclusion, he probably has that valuable talent known as physical intuition."
>
> Richard M. Sutton

PROBLEM: To experimentally examine the trajectory of a projectile.

APPARATUS:

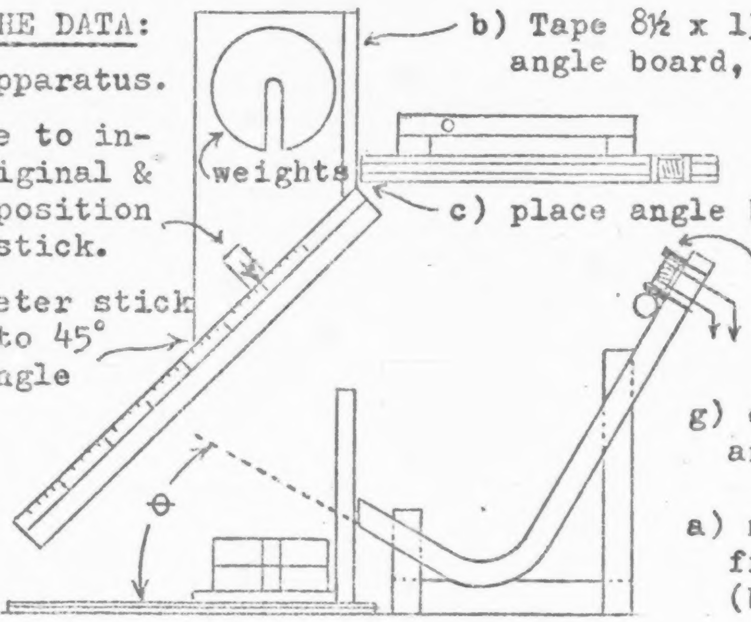
Launching pad	Electromagnet
Wired peg board	Angle board
White & carbon paper	Meter stick
1" dia. iron ball	Square
Wood frame & clamps	Rubber bands

REFERENCES:

1. Sutton, Am. Journal of Physics, pp. 805-6
2. Holton, Found. of Modern Physical Science, pp. 50-52

GATHERING THE DATA:

1. Set up apparatus.



b) Tape 8½ x 13 white paper on front of angle board, -- cover with carbon paper.

e) use tape to indicate original & integral position on meter stick.

c) place angle board against & ⊥ to launching pad.

f) position electromagnet at top of launching pad with rubber bands.

d) clamp meter stick parallel to 45° edge on angle board.

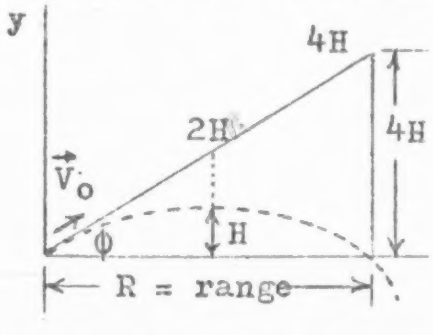
g) connect to pegboard switch and AC

a) mount launching pad on wood frame -- $\theta \doteq 30^\circ$ (but accurately measured)

2. Place ball against magnet and release.
3. Repeat step #2 as the angle board is moved successively back and laterally away from the launching pad in 5 cm. steps as measured along the meter stick. Note: ANGLE BOARD MUST BE KEPT AGAINST METER STICK THROUGHOUT TEST.
4. Draw vertical and horizontal axes through origin (the first mark) on white paper. Projectile impacts on white paper plot its actual trajectory.

SUMMATION:

1. Justify the following equations (show all calculations):



a) $x = V_o t \cos \phi$

b) $y = V_o t \sin \phi - \frac{gt^2}{2}$

c) $R = \frac{2V_o^2 \sin \phi \cos \phi}{g}$ Hint: $x = R \longrightarrow y = 0$

d) $y = x \left(1 - \frac{x}{R}\right) \tan \phi$ Hint: eliminate V_o & t from a, b, and c.

2. If H is the highest point in the trajectory, justify:
   a) the 2H and 4H values.
   b) $\tan \phi = \frac{4H}{R}$

has that valuable talent known as physical intuition."

Richard M. Sutton

PROBLEM: To experimentally examine the trajectory of a projectile.

APPARATUS:

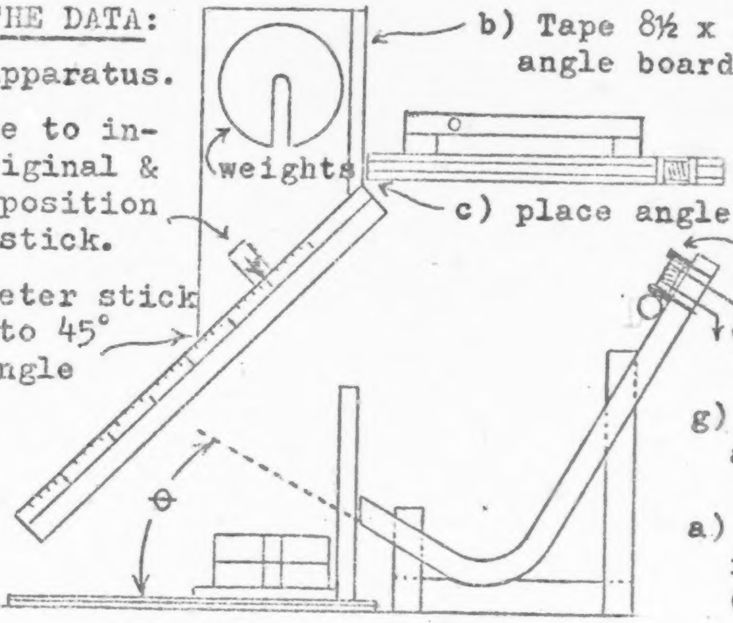
Launching pad
Wired peg board
White & carbon paper
1" dia. iron ball
Wood frame & clamps
Electromagnet
Angle board
Meter stick
Square
Rubber bands

REFERENCES:

1. Sutton, Am. Journal of Physics, pp. 805-6
2. Holton, Found. of Modern Physical Science, pp. 50-52

GATHERING THE DATA:

1. Set up apparatus.



e) use tape to indicate original & integral position on meter stick.

d) clamp meter stick parallel to 45° edge on angle board.

b) Tape 8½ x 13 white paper on front of angle board, -- cover with carbon paper.

c) place angle board against & ⊥ to launching pad.

f) position electromagnet at top of launching pad with rubber bands.

g) connect to pegboard switch and AC

a) mount launching pad on wood frame -- $\theta \doteq 30°$ (but accurately measured)

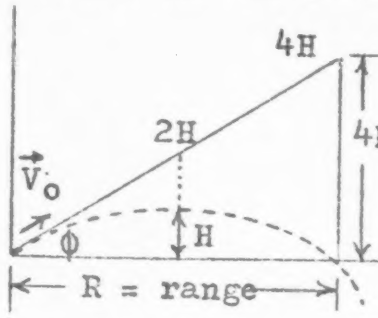
2. Place ball against magnet and release.

3. Repeat step #2 as the angle board is moved successively back and laterally away from the launching pad in 5 cm. steps as measured along the meter stick. Note: ANGLE BOARD MUST BE KEPT AGAINST METER STICK THROUGHOUT TEST.

4. Draw vertical and horizontal axes through origin (the first mark) on white paper. Projectile impacts on white paper plot its actual trajectory.

SUMMATION:

1. Justify the following equations (show all calculations):



a) $x = V_o t \cos \phi$

b) $y = V_o t \sin \phi - \frac{gt^2}{2}$

c) $R = \frac{2V_o^2 \sin \phi \cos \phi}{g}$ Hint: $x = R \rightarrow y = 0$

d) $y = x\left(1 - \frac{x}{R}\right) \tan \phi$ Hint: eliminate V_o & t from a, b, and c.

2. If H is the highest point in the trajectory, justify:
   a) the 2H and 4H values.
   b) $\tan \phi = \frac{4H}{R}$

3. Explain, in detail, why the trajectory as shown on paper represents the projectile's actual trajectory.

4. Test for "physical intuition." Diagnose the conclusion given in Prof. Sutton's introductory observation.

5. Using physical data, determine $\vec{V}_o$ as projectile leaves pad.

6. Show that projectile path is parabolic.

Station ⬡

Exp. # 40

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

Team ○

> "In order to reach the present frontier of knowledge, a scientist must travel a great distance and, if he is to push the frontier further back, he must reach it at the height of his powers. To do this he must start his journey early and direct his exploration along one line, but he must also limit his wanderings along the other alluring and tempting paths of learning. He has to make a personal sacrifice and purchase his scientific competence at the exhorbitant price of acquiescing in an all-encompassing intellectual innocence in fields outside his specialty....."
>
> George Sarton

PROBLEM: To experimentally relate water head and velocity.

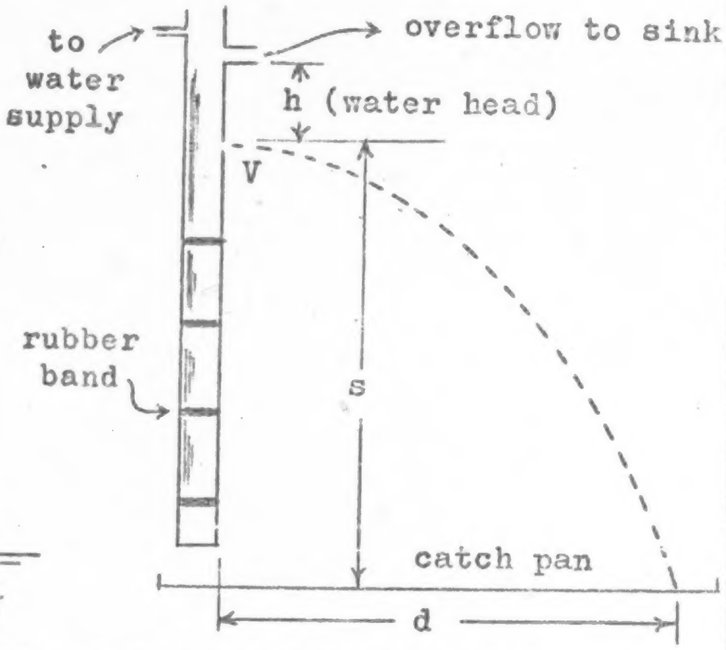
APPARATUS:

Triple beam balance
Water column & tubing
1000 cc grad. cylinder
Stop watch
Meter tape
Catch pans
1000cc beaker

REFERENCES:

1. White, Modern College Physics, pp. 201-3
2. Sears & Zemansky, University Physics, pp. 313-4

GATHERING THE DATA:



1. a) Adjust water input for overflow sufficient to maintain constant head with an orifice open.
   b) Open top orifice--recheck overflow and measure h, s, and d. (use center of stream to determine d)
   c) Repeat step b for the other orifices and record data in table:

h	s	d	V

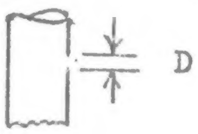
   d) Calculate V: $s = \frac{gt^2}{2}$, $d = Vt$ $\Big] \longrightarrow V = \frac{d}{\sqrt{\frac{2a}{g}}}$

2. a) Open top orifice and carefully determine water discharged in 60 seconds. (collect water in 1000cc beaker--determine volume Q via mass)
   b) Repeat step a for the other orifices and record data in table:

h	D	A	t	Q	V
	2mm		60 sec		

each orifice D = 2mm

A = orifice area



   c) Calculate water velocity via discharge rate:

$$Q = AV \longrightarrow V = \frac{Q}{A}.$$

> journey early and direct his exploration along one line, but he must also limit his wanderings along the other alluring and tempting paths of learning. He has to make a personal sacrifice and purchase his scientific competence at the exhorbitant price of acquiescing in an all-encompassing intellectual innocence in fields outside his specialty....."
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> George Sarton

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REFERENCES:

1. White, Modern College Physics, pp. 201-3
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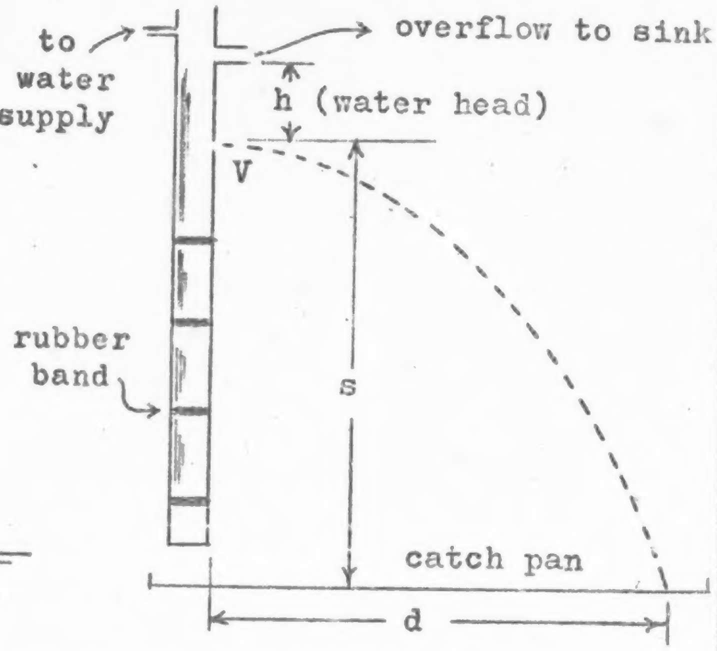
GATHERING THE DATA:



1. a) Adjust water input for overflow sufficient to maintain constant head with an orifice open.
   b) Open top orifice--recheck overflow and measure h, s, and d. (use center of stream to determine d)
   c) Repeat step b for the other orifices and record data in table:

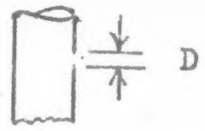
h	s	d	V

   d) Calculate V: $s = \frac{gt^2}{2}$, $d = Vt$ $\Big] \rightarrow V = \frac{d}{\sqrt{\frac{2s}{g}}}$

2. a) Open top orifice and carefully determine water discharged in 60 seconds. (collect water in 1000cc beaker--determine volume Q via mass)
   b) Repeat step a for the other orifices and record data in table:

h	D	A	t	Q	V
	2mm		60 sec		

each orifice D = 2mm
A = orifice area



   c) Calculate water velocity via discharge rate:

$$Q = AV \rightarrow V = \frac{Q}{A}.$$

SUMMATION:

1. Explain physics and mathematics of #1d and #2c.
2. Compare velocities determined in steps #1 and #2 of GATHERING THE DATA with velocities determined by Torricelli's Theorem:

$$V = \sqrt{2gh}$$

3. Derive Torricelli's Theorem from Bernoulli's Equation.
4. Assuming sharp edged orifice, use data of step #2 GATHERING THE DATA and Torricelli's Theorem to determine the actual "vena contracta" of the various openings. Compare with figure given by Sears and Zemansky.

Station AVIATION HIGH SCHOOL Exp.# 41 APPLIED PHYSICS LABORATORY Team

> "No fewer than 120 of the descendants of the mathematical Bernoullis have been traced genealogically,... the majority achieved distinction--sometimes amounting to eminence--in law, scholarship, science, literature ... None were failures."
>
> E. T. Bell
>
> " 'The Bernoullis,' Galton says, 'were mostly quarrelsome and unamiable;' John was a prime example. He was violent, abusive, jealous, and when necessary, dishonest... His son Daniel, again a brilliant mathematician, had the temerity to win a French Academy of Science prize which his father had sought. John gave him a special reward by throwing him out of the house..."
>
> James R. Newman

PROBLEM: To construct a manometer, to measure pressures in a venturi tube, and to derive Bernoulli's equation.

APPARATUS:

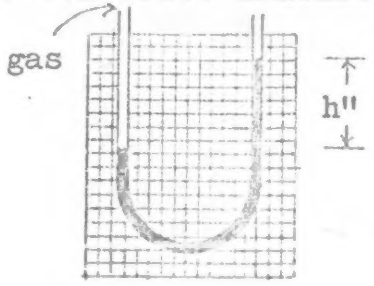
Wind generator
Venturi tube
Bent tubing
Angle board
Formica board
1/10" graph paper

REFERENCES:

1. Beiser, The Science of Physics, pp. 156-62
2. MacLachlan, Matter & Energy, pp. 112-14
3. Halliday & Resnick, Physics, pp. 376-80
4. Sears and Zemansky, University Physics, pp. 311-13

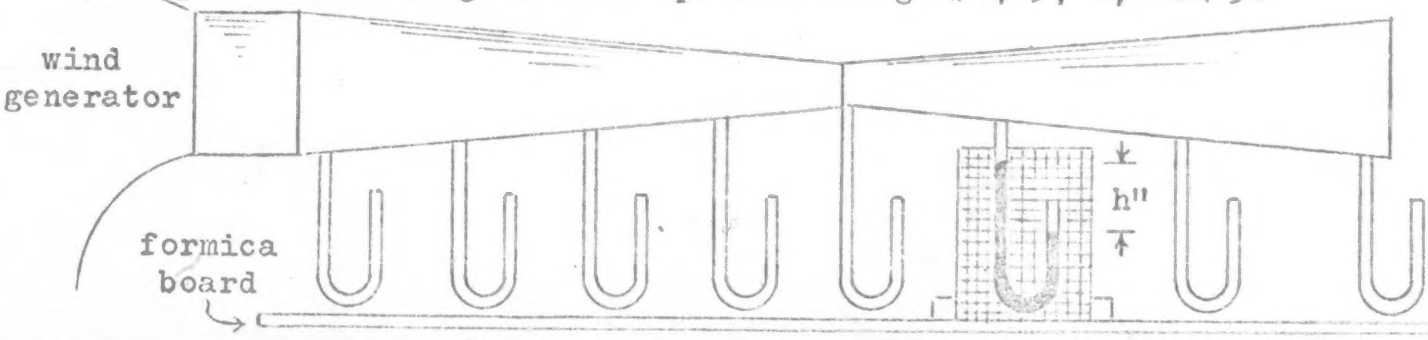
GATHERING THE DATA:

1. Construct manometer and measure laboratory gas pressure in psi.



   a) partially fill tube with water.
   b) slip graph paper behind tube and adjust paper so that water levels in both tubes line up with paper.
   c) connect gas to manometer
   d) measure h to nearest .01"
   e) calculate pressure = $(0.43 \times \frac{h''}{12})$ psi

2. Check venturi tube pressures for different wind generator settings.
   a) set up wind generator and venturi as shown.
   b) fill tubes approx. halfway with water.
   c) set wind generator on speed setting #1 and plug in.
   d) using graph paper on angle board, measure and record h.
   e) calculate venturi tube absolute pressures and record in table.
   f) repeat for wind generator speed settings #2, 3, 4, and 5.



Speed setting	h	psi	h	psi	h	psi	h	psi	h	psi	h	psi	h	psi	h	psi
1																

E. T. Bell

> " 'The Bernoullis,' Galton says, 'were mostly quarrelsome and unamiable;' John was a prime example. He was violent, abusive, jealous, and when necessary, dishonest... His son Daniel, again a brilliant mathematician, had the temerity to win a French Academy of Science prize which his father had sought. John gave him a special reward by throwing him out of the house..."
>
> James R. Newman

PROBLEM: To construct a manometer, to measure pressures in a venturi tube, and to derive Bernoulli's equation.

APPARATUS:

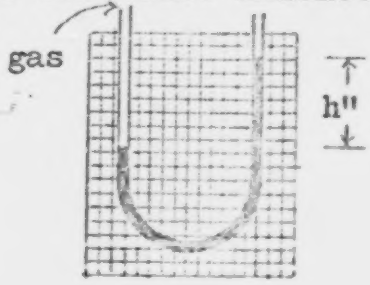
Wind generator
Venturi tube
Bent tubing
Angle board
Formica board
1/10" graph paper

REFERENCES:

1. Beiser, The Science of Physics, pp. 156-62
2. MacLachlan, Matter & Energy, pp. 112-14
3. Halliday & Resnick, Physics, pp. 376-80
4. Sears and Zemansky, University Physics, pp. 311-13

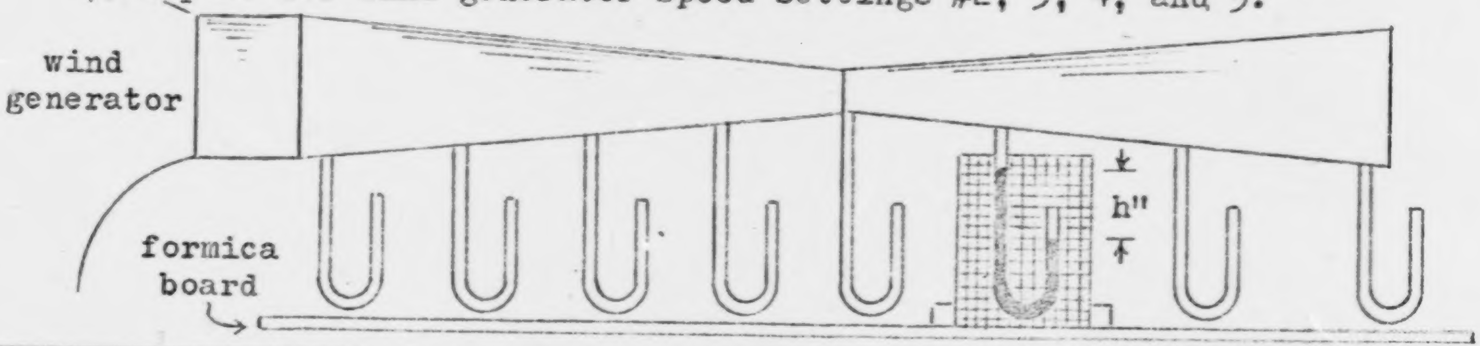
GATHERING THE DATA:

1. Construct manometer and measure laboratory gas pressure in psi.



   a) partially fill tube with water.
   b) slip graph paper behind tube and adjust paper so that water levels in both tubes line up with paper.
   c) connect gas to manometer
   d) measure h to nearest .01"
   e) calculate pressure = $(0.43 \times \frac{h''}{12})$ psi

2. Check venturi tube pressures for different wind generator settings.
   a) set up wind generator and venturi as shown.
   b) fill tubes approx. halfway with water.
   c) set wind generator on speed setting #1 and plug in.
   d) using graph paper on angle board, measure and record h.
   e) calculate venturi tube absolute pressures and record in table.
   f) repeat for wind generator speed settings #2, 3, 4, and 5.



Speed setting	h	psi	h	psi	h	psi	h	psi	h	psi	h	psi	h	psi	h	psi
1																
5																

SUMMATION:

1. According to data, where is pressure greatest in a venturi tube? Least?
2. How would manometers filled with mercury have affected results? Alcohol?
3. Justify equation # 1e.
4. Derive Bernoulli's equation using the conservation of energy principle. Justify each step.
5. According to Beiser: "Air is, of course, a compressible fluid and so does not fit our model exactly, but the behavior predicted by Bernoulli's equation is not a bad approximation for gases at moderate speeds."
   Calculate air speed at point of least pressure for each speed setting.

Station ⬡ Exp.# 42 Team ○

AVIATION HIGH SCHOOL **APPLIED PHYSICS LABORATORY**

> "I would rather discover one law of nature than be king of the Persians."
>
> Democritus
>
> "Sic transit gloria--but not for the man who discovers a law of nature. He has already begun to live forever."
>
> W. V. Houston

PROBLEM: To construct and calibrate a wind speed indicator.

APPARATUS:

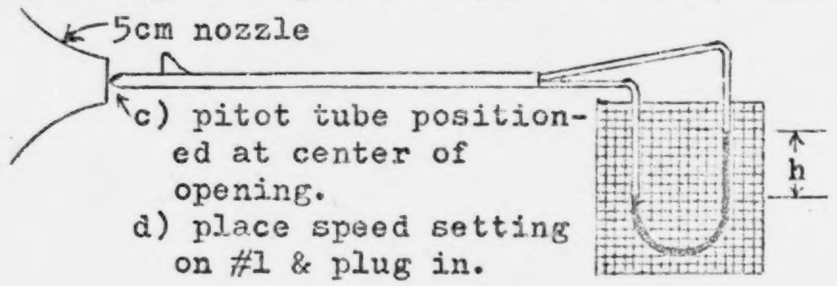
Wind generator
Universal manometer
1/10" graph paper
Nozzles
Pitot tube and tubing
Angle board and U tube
Board, tubing, & clamps

REFERENCES:

1. Halliday & Resnick, Physics, pp. 380-82
2. Sears & Zemansky, University Physics, pp. 316-17
3. Bluh & Elder, Physics App. and Principles, pp. 113-15
4. Beiser, The Science of Physics, p. 154

GATHERING THE DATA:

1. Set up wind generator, pitot tube, and U tube as shown.



c) pitot tube positioned at center of opening.
d) place speed setting on #1 & plug in.

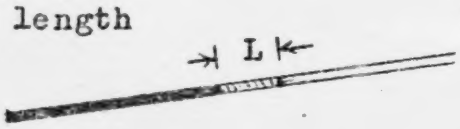
a) partially fill U tube with water before connecting tubing.
b) slip 1/10" graph paper behind U tube--line up horizontal lines parallel to water level.
e) measure h to nearest .01"
f) calculate $v = \sqrt{\frac{2ghd'}{d}}$ where d' = density of water; g in ft/sec^2
d = density of air; h converted to ft.
g) repeat for speed settings #2, 3, 4, and 5.
h) repeat for other nozzles.

Speed Setting #	Openings							
	5cm		10cm		18cm		30cm	
	h'	v(ft/sec)	h'	v(ft/sec)	h'	v(ft/sec)	h'	v(ft/sec)
1								
5								

2. Measure air velocities again, using universal manometer. Record data in table.

3. Calibrate the constructed wind speed indicator to read ft/sec directly. (Use graph paper)

Note: water rises 1"/20" of tube length



v (ft/sec)	$L'' = v^2 \times \frac{d}{2(12)(20)gd'}$
5	
55	
60	

4. Measure air speeds using calibrated wind speed indicator. Record data in table.

SUMMATION:

nature. He has already begun to live forever." W. V. Houston

PROBLEM: To construct and calibrate a wind speed indicator.

APPARATUS:

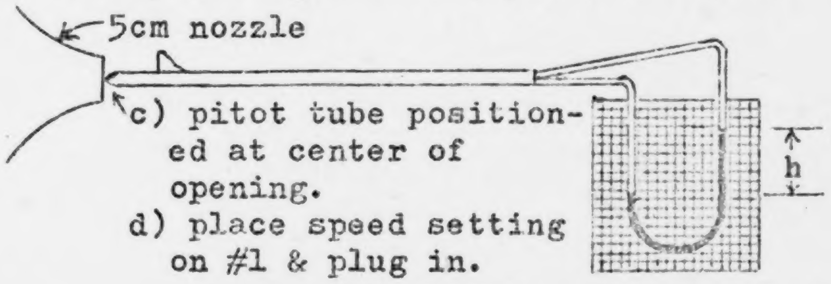
Wind generator
Universal manometer
1/10" graph paper
Nozzles
Pitot tube and tubing
Angle board and U tube
Board, tubing, & clamps

REFERENCES:

1. Halliday & Resnick, Physics, pp. 380-82
2. Sears & Zemansky, University Physics, pp. 316-17
3. Bluh & Elder, Physics App. and Principles, pp. 113-15
4. Beiser, The Science of Physics, p. 154

GATHERING THE DATA:

1. Set up wind generator, pitot tube, and U tube as shown.



a) partially fill U tube with water before connecting tubing.

b) slip 1/10" graph paper behind U tube--line up horizontal lines parallel to water level.

c) pitot tube positioned at center of opening.

d) place speed setting on #1 & plug in.

e) measure h to nearest .01"

f) calculate $v = \sqrt{\frac{2ghd'}{d}}$ where d' = density of water; g in ft/sec^2
d = density of air; h converted to ft.

g) repeat for speed settings #2, 3, 4, and 5.

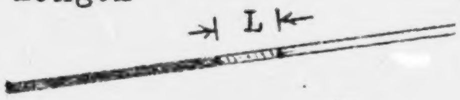
h) repeat for other nozzles.

Speed Setting #	Openings							
	5cm		10cm		18cm		30cm	
	h'	v(ft/sec)	h'	v(ft/sec)	h'	v(ft/sec)	h'	v(ft/sec)
1								
5								

2. Measure air velocities again, using universal manometer. Record data in table.

3. Calibrate the constructed wind speed indicator to read ft/sec directly. (Use graph paper)

Note: water rises 1"/20" of tube length



v (ft/sec)	$L'' = v^2 \times \frac{d}{2(12)(20)gd'}$
5	
55	
60	

4. Measure air speeds using calibrated wind speed indicator. Record data in table.

SUMMATION:

1. a) Which nozzle opening yields the greatest wind velocity?
b) Is there a mathematical relation between nozzle opening and air speed?

2. Which manometer is most sensitive?
Can its sensitivity be increased? Explain.

3. Derive equation $v = \sqrt{\frac{2ghd'}{d}}$ from Bernoulli's equation.

Station

Exp.# 43

Team

AVIATION HIGH SCHOOL

APPLIED PHYSICS LABORATORY

> "Outside of engineering circles, torque is generally called 'moment of force', because 'moment' is a Latin word which means importance; and since the product Fr measures the importance of a force in producing rotation it is appropriately called moment of force. The word is used ... in the same sense in which Shakespeare employs it when he speaks of 'enterprises of pith and moment'."
>
> Henry Crew

PROBLEM: To calibrate a torque wrench and to apply the double weight method.

APPARATUS:

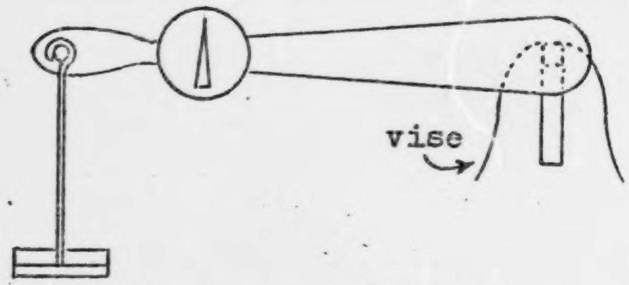
Torque wrench & sockets	Level
Avoirdupois scale	Clamps
0-1 lb. wt. set	Torque tester
Assorted weights & hooks	Vise & bolt

REFERENCES:

1. Lehrman & Swarts, Foundations of Physics, pp.119-21
2. Stollberg & Hill, Physics, pp. 165-6

GATHERING THE DATA:

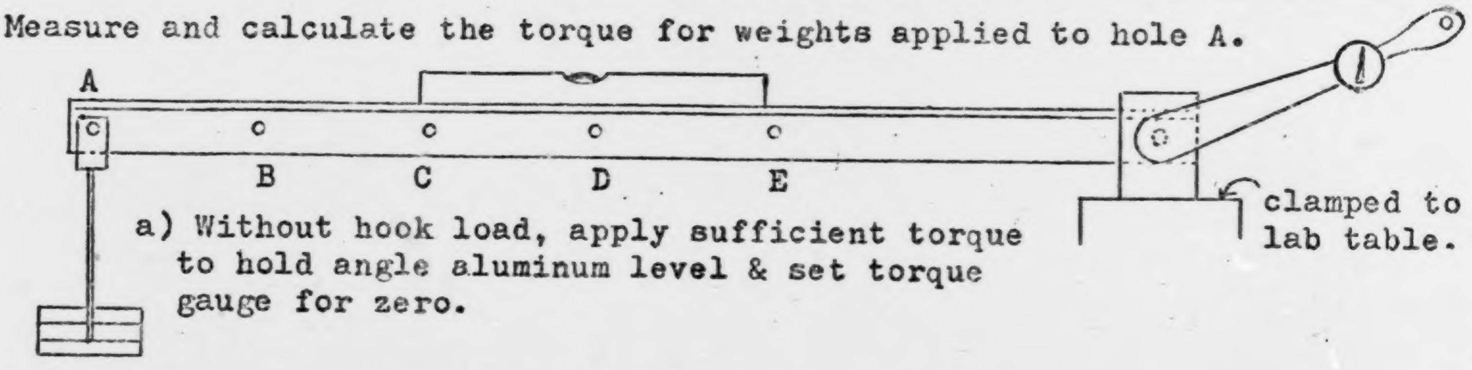
1. Calibrate torque wrench.
   - a) Measure distance from center of hole in handle to center of square drive. --convert to ft.& record in table.
   - b) Mount torque wrench in vise. --hold on square drive. --verify that line joining centers of hole and square drive is level.



   - c) Insert bolt in hole in handle and adjust torque wrench gauge to read zero.
   - d) Hang weight hook on bolt as shown and load until torque wrench gauge registers a torque of 4 lb. ft. Record in table.
   - e) Repeat d for successive 2 lb. ft. torque increments up to 40 lb. ft.
   - f) Complete table:

L Torque Meter (lb. ft.)	Weight (lbs)	Torque Arm (ft.)	L' Torque (lb.x ft.)	L - L' (lb.ft.)	% error = $\frac{L-L'}{L'}$
4					
6					
40					

2. Measure and calculate the torque for weights applied to hole A.



   - a) Without hook load, apply sufficient torque to hold angle aluminum level & set torque gauge for zero.
   - b) Add 2 lb., including hook, to hole A and record torque gauge reading to keep angle aluminum level.
   - c) Compare calculated torque & gauge reading.
   - d) Repeat b & c for successive 1 lb. increments. DO NOT EXCEED 40 lb. ft. TORQUE!!!

Torque	
Gauge	Calculated

> force in producing rotation it is appropriately called moment of force. The word is used ... in the same sense in which Shakespeare employs it when he speaks of 'enterprises of pith and moment'."
>
> Henry Crew

PROBLEM: To calibrate a torque wrench and to apply the double weight method.

APPARATUS:

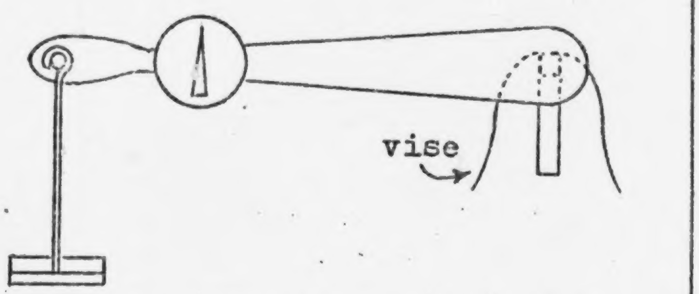
Torque wrench & sockets	Level
Avoirdupois scale	Clamps
0-1 lb. wt. set	Torque tester
Assorted weights & hooks	Vise & bolt

REFERENCES:

1. Lehrman & Swarts, Foundations of Physics, pp.119-21
2. Stollberg & Hill, Physics, pp. 165-6

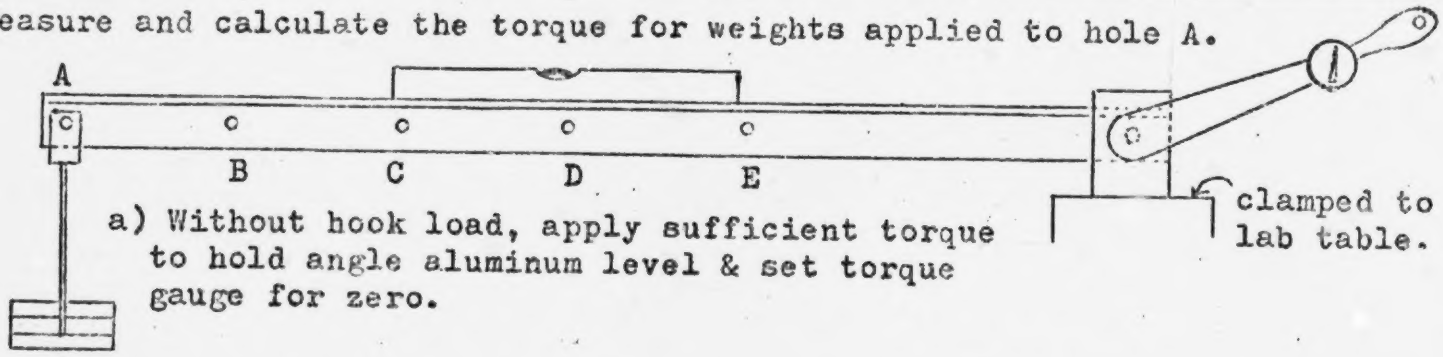
GATHERING THE DATA:

1. Calibrate torque wrench.
   a) Measure distance from center of hole in handle to center of square drive.
   --convert to ft.& record in table.
   b) Mount torque wrench in vise.
   --hold on square drive.
   --verify that line joining centers of hole and square drive is level.
   c) Insert bolt in hole in handle and adjust torque wrench gauge to read zero.
   d) Hang weight hook on bolt as shown and load until torque wrench gauge registers a torque of 4 lb. ft. Record in table.
   e) Repeat d for successive 2 lb. ft. torque increments up to 40 lb. ft.
   f) Complete table:



L Torque Meter (lb. ft.)	Weight (lbs)	Torque Arm (ft.)	L' Torque (lb.x ft.)	L - L' (lb.ft.)	% error = $\frac{L-L'}{L'}$
4					
6					
40					

2. Measure and calculate the torque for weights applied to hole A.

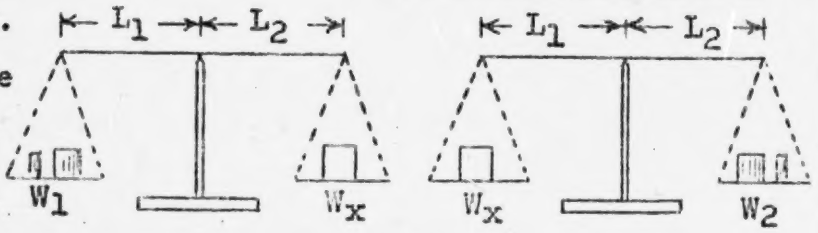


   a) Without hook load, apply sufficient torque to hold angle aluminum level & set torque gauge for zero.
   b) Add 2 lb., including hook, to hole A and record torque gauge reading to keep angle aluminum level.
   c) Compare calculated torque & gauge reading.
   d) Repeat b & c for successive 1 lb. increments.
   DO NOT EXCEED 40 lb. ft. TORQUE!!!

Torque	
Gauge	Calculated

3. Repeat #2 for holes B, C, D, and E.
4. Measure weight W_x on simple balance & then apply double weight method:

$$W_x = \sqrt{W_1 W_2}$$



SUMMATION:

1. How does torque vary with weight (force)? With arm length?
2. Why must angle aluminum be level when making gauge readings in #2 of GATHERING THE DATA?
3. Derive equation: $W_x = \sqrt{W_1 W_2}$
4. What error is eliminated by double weighing?

Station

Exp.# 44

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

"The magnitudes whether commensurable or incommensurable balance at distances reciprocally proportional to the magnitudes."

Archimedes

PROBLEM: To apply moments in locating the center of gravity of an airplane under varied loading distributions.

APPARATUS:

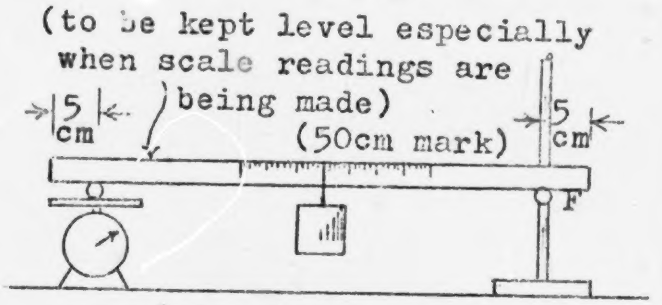
3 dietetic scales	Airplane
Blocks & rollers	Cord
Iron stand & arm	Plumb bob
2 meter sticks	Level
Gm "wt" set	

REFERENCES:

1. Lehrman & Swartz, Found. of Physics, pp. 121-4
2. Stollberg & Hill, Physics, pp. 164-7

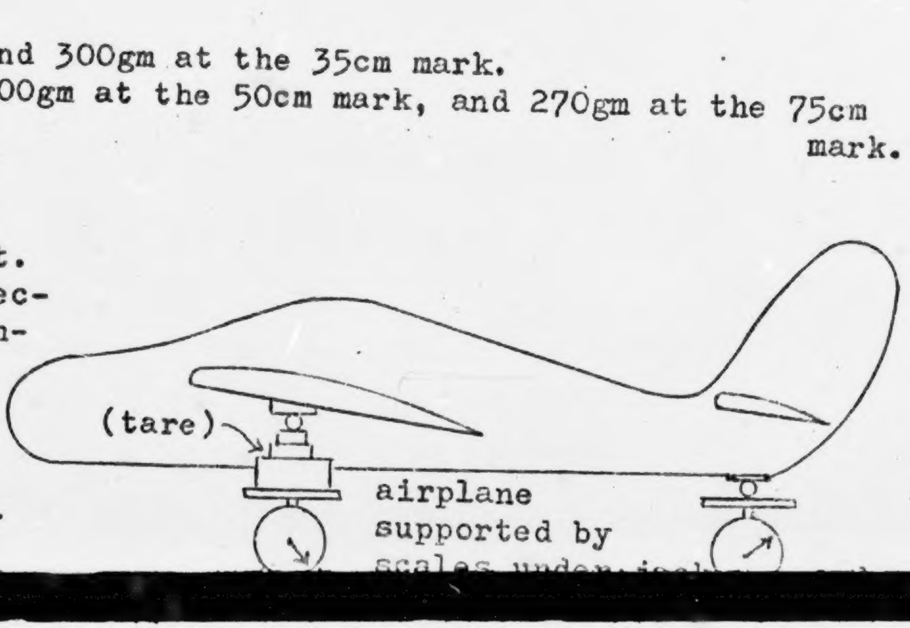
GATHERING THE DATA:

1. a) Set up apparatus as shown:
   b) Place 100 gm "wt" at 50cm mark and calculate the moments about the fulcrum F. Identify the clockwise & counter clockwise moments about F.
   c) Considering clockwise moments negative & counter clockwise moments positive, what is the sum of the moments?
   d) What is the magnitude & direction of the force exerted by the fulcrum? (does it have a moment about F?)


(to be kept level especially when scale readings are being made)
5 cm
5 cm
(50cm mark)
F

(set scale for zero without weight in place and then can ignore weight of meter stick)

2. Repeat step #1 for 200gm, 500gm, and then 1000gm at the 50cm mark. What is the relation between:
   a) the scale reading and the load in each case?
   b) the moments?
   c) the distances to the fulcrum?
3. Place 450gm at the meter sticks 65cm mark. What is the relation of the:
   a) scale reading to the load?
   b) distances to the fulcrum?
   c) clockwise and counter clockwise moments about F?
4. Simultaneously place 300gm at 65cm mark and 150gm at the 35cm mark. Calculate the sum of the moments.
5. Repeat step #4 for:
   a) 450gm at the 55cm mark and 300gm at the 35cm mark.
   b) 90gm at the 25cm mark, 200gm at the 50cm mark, and 270gm at the 75cm mark.
6. Mount airplane on 3 dietetic scales--use blocks to level--support at jack pads.
   a) Determine airplane weight.
   b) From where & in what direction can this force be considered to act?
   c) Using airplane nose as datum (ref. for moment distances) & using moment principles, find the location of the airplane's



airplane supported by scales under jack

PROBLEM: To apply moments in locating the center of gravity of an airplane under varied loading distributions.

APPARATUS:

3 dietetic scales	Airplane
Blocks & rollers	Cord
Iron stand & arm	Plumb bob
2 meter sticks	Level
Gm "wt" set	

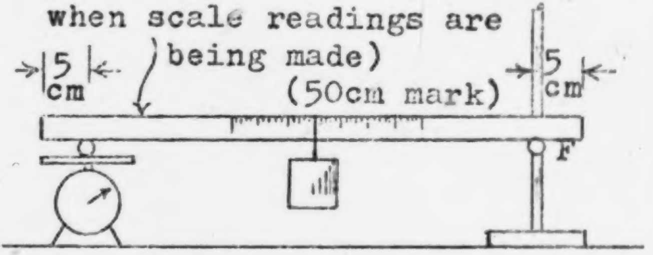
REFERENCES:

1. Lehrman & Swartz, Found. of Physics, pp. 121-4
2. Stollberg & Hill, Physics, pp. 164-7

GATHERING THE DATA:

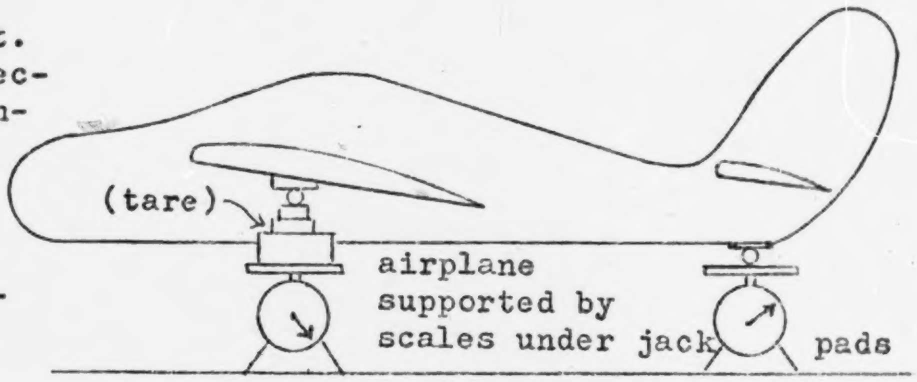
1. a) Set up apparatus as shown:
   b) Place 100 gm "wt" at 50cm mark and calculate the moments about the fulcrum F. Identify the clockwise & counter clockwise moments about F.
   c) Considering clockwise moments negative & counter clockwise moments positive, what is the sum of the moments?
   d) What is the magnitude & direction of the force exerted by the fulcrum? (does it have a moment about F?)

(to be kept level especially when scale readings are being made)



(set scale for zero without weight in place and then can ignore weight of meter stick)

2. Repeat step #1 for 200gm, 500gm, and then 1000gm at the 50cm mark. What is the relation between:
   a) the scale reading and the load in each case?
   b) the moments?
   c) the distances to the fulcrum?
3. Place 450gm at the meter sticks 65cm mark. What is the relation of the:
   a) scale reading to the load?
   b) distances to the fulcrum?
   c) clockwise and counter clockwise moments about F?
4. Simultaneously place 300gm at 65cm mark and 150gm at the 35cm mark. Calculate the sum of the moments.
5. Repeat step #4 for:
   a) 450gm at the 55cm mark and 300gm at the 35cm mark.
   b) 90gm at the 25cm mark, 200gm at the 50cm mark, and 270gm at the 75cm mark.
6. Mount airplane on 3 dietetic scales--use blocks to level--support at jack pads.
   a) Determine airplane weight.
   b) From where & in what direction can this force be considered to act?
   c) Using airplane nose as datum (ref. for moment distances) & using moment principles, find the location of the airplane's center of gravity with respect to its nose.



7. Repeat step #6 after adding 200gm load 15 cm aft of wings leading edge. (Include 200gm load as part of new weight of airplane)
8. Repeat step #6 after adding 500gm load 20cm aft of wing's leading edge.

SUMMATION:

1. Why can weight of meter stick be ignored in step #1?
2. Has experimental data verified Archimedes' observation?
3. What happens to an airplane's center of gravity as passengers walk about and as fuel is consumed?
4. What is the sum of the moments when a body is in equilibrium?

Station ⬡ AVIATION HIGH SCHOOL- Exp.# 45 APPLIED PHYSICS LABORATORY Team ○

> "...in previous generations the distinction between pure and applied science was less pronounced than it is today. The three greatest pure mathematicians--Archimedes, Newton, and Gauss--were also great applied mathematicians; to these one can add the three greatest pure mathematicians of the 20th century--Poincare, Hilbert, and von Neumann--each of whom was also a great applied mathematician."
>
> Alvin Weinberg

PROBLEM: To locate centers of gravity and to contrast the mathematical and the physical methods of locating centers of gravity.

APPARATUS:

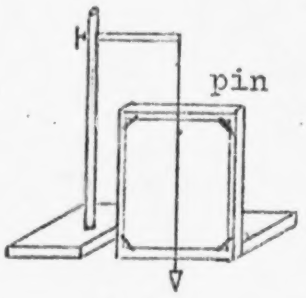
Triple Beam Balance
Iron stand & arm
Plumb bob & cord
Cardboard figures
Masonite angle
White paper
Meter stick
Punch
Tape
Pin
C clamp

REFERENCES:

1. White, Modern College Physics, pp. 129-32
2. Sears & Zemansky, University Physics, pp. 54-7
3. Halliday & Resnick, Physics, pp. 265-8
4. Gale, Am.Journal of Physics, Vol. 22 p. 474

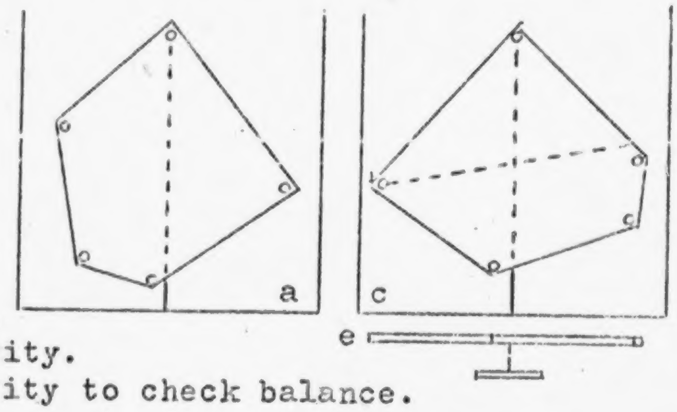
GATHERING THE DATA:

1. a) Trace cardboard figures using metal masters.
   b) Cut figures using paper cutter.
   c) Punch small holes in corners of figures.



2. a) Clamp masonite angle to lab table.
   b) Tape white paper to masonite.
   c) Use plumb line to get vertical line on paper through pin (will serve as plumb line for subsequent tests)

3. Locate centers of gravity on figures A_1 and A_2.
   a) Mount figure on pin and rock back and forth.
   b) When motion ceases, draw line from pin to plumb line as shown. (repeat several times to assure consistent results)
   c) Repeat steps a & b using other holes.
   d) Intersection indicates center of gravity.
   e) Mount figure on pin at center of gravity to check balance.



4. Locate center of gravity of figure B and then:
   a) Arbitrarily cut B into two parts, locating the center of gravity of each part.
   b) Piece parts together to make original form and join the new centers of gravity together. What is the relation of this line to the center of gravity of the entire figure B?
   c) Determine the mass of each part and calculate the moments of each of the parts about the center of gravity of figure B.
   d) How do the masses, moments, and moment arms compare?

5. Locate centers of gravity of triangles C_1 and C_2. According to experimental results, what geometric lines are required?

6. Using step #5 data, locate the centers of gravity of D_1 & D_2 geometrically.

7. Geometrically locate the center of gravity of quadrilateral E.
   a) divide into 2 triangles, locate the cg of each & join.

greatest pure mathematicians of the 20th century--Poincare, Hilbert, and von Neumann--each of whom was also a great applied mathematician."

Alvin Weinberg

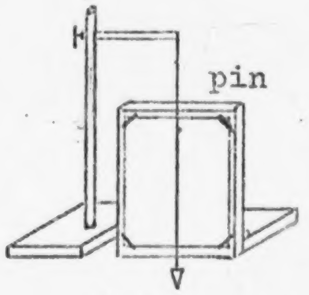
PROBLEM: To locate centers of gravity and to contrast the mathematical and the physical methods of locating centers of gravity.

APPARATUS:		REFERENCES:
Triple Beam Balance	Meter stick	1. White, Modern College Physics, pp. 129-32
Iron stand & arm	Punch	2. Sears & Zemansky, University Physics, pp. 54-7
Plumb bob & cord	Tape	3. Halliday & Resnick, Physics, pp. 265-8
Cardboard figures	Pin	4. Gale, Am.Journal of Physics, Vol. 22 p. 474
Masonite angle	C clamp	
White paper		

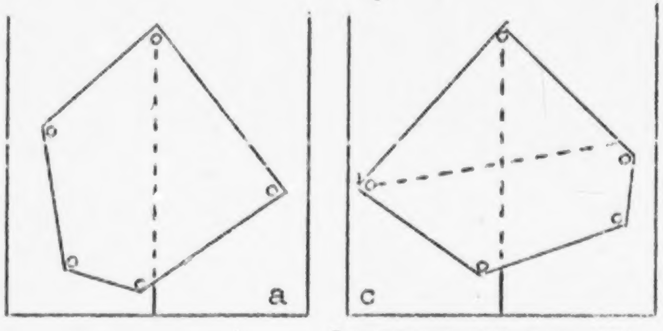
GATHERING THE DATA:

1. a) Trace cardboard figures using metal masters.
   b) Cut figures using paper cutter.
   c) Punch small holes in corners of figures.

2. a) Clamp masonite angle to lab table.
   b) Tape white paper to masonite.
   c) Use plumb line to get vertical line on paper through pin (will serve as plumb line for subsequent tests)



3. Locate centers of gravity on figures A_1 and A_2.
   a) Mount figure on pin and rock back and forth.
   b) When motion ceases, draw line from pin to plumb line as shown. (repeat several times to assure consistent results)
   c) Repeat steps a & b using other holes.
   d) Intersection indicates center of gravity.
   e) Mount figure on pin at center of gravity to check balance.



4. Locate center of gravity of figure B and then:
   a) Arbitrarily cut B into two parts, locating the center of gravity of each part.
   b) Piece parts together to make original form and join the new centers of gravity together. What is the relation of this line to the center of gravity of the entire figure B?
   c) Determine the mass of each part and calculate the moments of each of the parts about the center of gravity of figure B.
   d) How do the masses, moments, and moment arms compare?

5. Locate centers of gravity of triangles C_1 and C_2. According to experimental results, what geometric lines are required?

6. Using step #5 data, locate the centers of gravity of D_1 & D_2 geometrically.

7. Geometrically locate the center of gravity of quadrilateral E.
   a) divide into 2 triangles, locate the cg of each & join.
   b) divide into 2 other triangles, repeat a and intersection of these lines is the center of gravity of the quadrilateral.

8. Cut figure E into 2 triangles & check their masses & their moments about the center of gravity of figure E.

SUMMATION:

1. Discuss adv. & disadv. of the physical & mathematical approaches to cg
2. Where are the cg's of the objects considered actually located?
3. "If a triangle is divided into 2 parts by a line drawn through the vertex & the cg, the 2 triangles so formed have equal areas & the line connecting their centroids is parallel to the side opposite (the vertex) & is one third the length of that side." Demonstrate. Test.

Station

Exp. # 46

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "The earliest balances known are probably those pictured in Egyptian sculptures, which present the dead man in the presence of the great god Osiris, watching his soul on one pan of the balance being weighed against right and truth in the other pan. The jar on the left pan symbolizes the man's mind and heart; the feather on the right stands for truth and justice."
>
> Henry Crew

PROBLEM: To measure weights with an analytic balance using the method of vibrations and balance sensitivity. To consider buoyancy in water and in air.

APPARATUS:

Analytic balance
Standard mass set
Triple beam balance
250gm spring balance
250ml grad. cylinder
Weights A and B

REFERENCES:

1. Engelder, Elementary Quantitative Analysis, pp. 21-28
2. Sears & Zemansky, University Physics, pp. 287-9
3. Halliday & Resnick, Physics, pp. 362-4
4. Gamow, Physics Found. and Frontiers, pp. 20-21

GATHERING THE DATA:

1. Read analytic balance instructions. DO NOT OPEN WINDOW!
2. Adjust analytic balance's base screws until spirit level indicates level.
3. Determine analytic balance's zero point by method of vibrations.
   Note: zero point is the point where the pointer would come to rest and usually is not exactly in the middle of the scale.
   a) Release pan and beam arrestments and take 5 successive readings, three at the extreme left #1, #3, & #5 and two on extreme right #2 & #4.
   --estimate readings to 0.1 of a division.
   --if vibrations too vigorous (or weak) raise beam & release again.

$$\text{b) Zero point} = \frac{\frac{\#1 + \#3 + \#5}{3} + \frac{\#2 + \#4}{2}}{2}$$

   c) Repeat a and b to check consistency. Raise beam when finished.
4. Check weight of object A.
   ALWAYS RAISE BEAM BEFORE OPENING WINDOW OR CHANGING WEIGHTS!
   a) Approximate weight of object A on triple beam balance.
   b) Place wt. A on left pan--always use tweezers to handle wts.
   c) Place approx. balance wt. as determined by step 4a in right pan.
   d) Close window, lower beam--observe pointer movement and judge if weight should be added to or taken away from the right pan.
   e) When balance wt. correctly selected to bring pointer readings within range of scale, determine pt. of rest as in step #3a:

$$\text{Point of Rest} = \frac{\frac{\#1 + \#3 + \#5}{3} + \frac{\#2 + \#4}{2}}{2}$$

   f) If Zero Point ≠ Point of Rest, det. Sensitivity of Balance (the deflection produced by 1mg in pan--use rider and moments)

$$\text{Wt. of A} = \text{Balance wt.} \pm W' \quad \text{where } W' = \frac{\text{Zero Pt.} \pm \text{Pt. of Rest}}{\text{Sensitivity}}$$

5. Check weight of team signatures (use 3 x 5 card).

a) Check weight of object B in air.

the left pan symbolizes the man's mind and heart; the feather on the right stands for truth and justice."

Henry Crew

PROBLEM: To measure weights with an analytic balance using the method of vibrations and balance sensitivity. To consider buoyancy in water and in air.

APPARATUS:

Analytic balance
Standard mass set
Triple beam balance
250gm spring balance
250ml grad. cylinder
Weights A and B

REFERENCES:

1. Engelder, Elementary Quantitative Analysis, pp. 21-28
2. Sears & Zemansky, University Physics, pp. 287-9
3. Halliday & Resnick, Physics, pp. 362-4
4. Gamow, Physics Found. and Frontiers, pp. 20-21

GATHERING THE DATA:

1. Read analytic balance instructions. DO NOT OPEN WINDOW!

2. Adjust analytic balance's base screws until spirit level indicates level.

3. Determine analytic balance's zero point by method of vibrations.
   Note: zero point is the point where the pointer would come to rest and usually is not exactly in the middle of the scale.
   a) Release pan and beam arrestments and take 5 successive readings, three at the extreme left #1, #3, & #5 and two on extreme right #2 & #4.
   --estimate readings to 0.1 of a division.
   --if vibrations too vigorous (or weak) raise beam & release again.
   b) Zero point $= \dfrac{\dfrac{\#1 + \#3 + \#5}{3} + \dfrac{\#2 + \#4}{2}}{2}$
   c) Repeat a and b to check consistency. Raise beam when finished.

4. Check weight of object A.
   ALWAYS RAISE BEAM BEFORE OPENING WINDOW OR CHANGING WEIGHTS!
   a) Approximate weight of object A on triple beam balance.
   b) Place wt. A on left pan--always use tweezers to handle wts.
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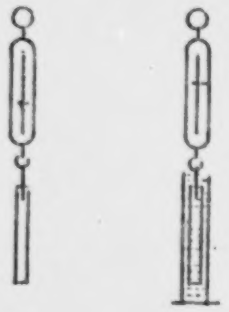
   f) If Zero Point ≠ Point of Rest, det. Sensitivity of Balance (the deflection produced by 1mg in pan--use rider and moments)

$$\text{Wt. of A} = \text{Balance wt.} \pm W' \quad \text{where } W' = \frac{\text{Zero Pt.} \pm \text{Pt. of Rest}}{\text{Sensitivity}}$$

5. Check weight of team signatures (use 3 x 5 card).

6. a) Check weight of object B in air.
   b) Check weight of object B submerged in water.



SUMMATION:

1. Why is weight of object in water less than that in air? How much less?

2. Is the weight of an object in a vacuum less than or more than that in air? (see attached card for complete discussion)

Station ⬡ Exp. # 47 Team ○

AVIATION HIGH SCHOOL **APPLIED PHYSICS LABORATORY**

> "Boyle and Hooke lamented that of all natural phenomena gravitation is the least explainable... Newton himself frequently acknowledged that he did not know the cause of gravitation... In the general scholium to his great work (Principia Mathematica) he plainly states: 'Hitherto I have not been able to discover the cause...of gravity from phenomena, and I frame no hypothesis...the cause of gravity is what I do not pretend to know...' ".
>
> J. A. Weisheipl, O.P.

PROBLEM: To experimentally examine velocity, energy, momentum, and impulse factors in "pile driving."

APPARATUS:

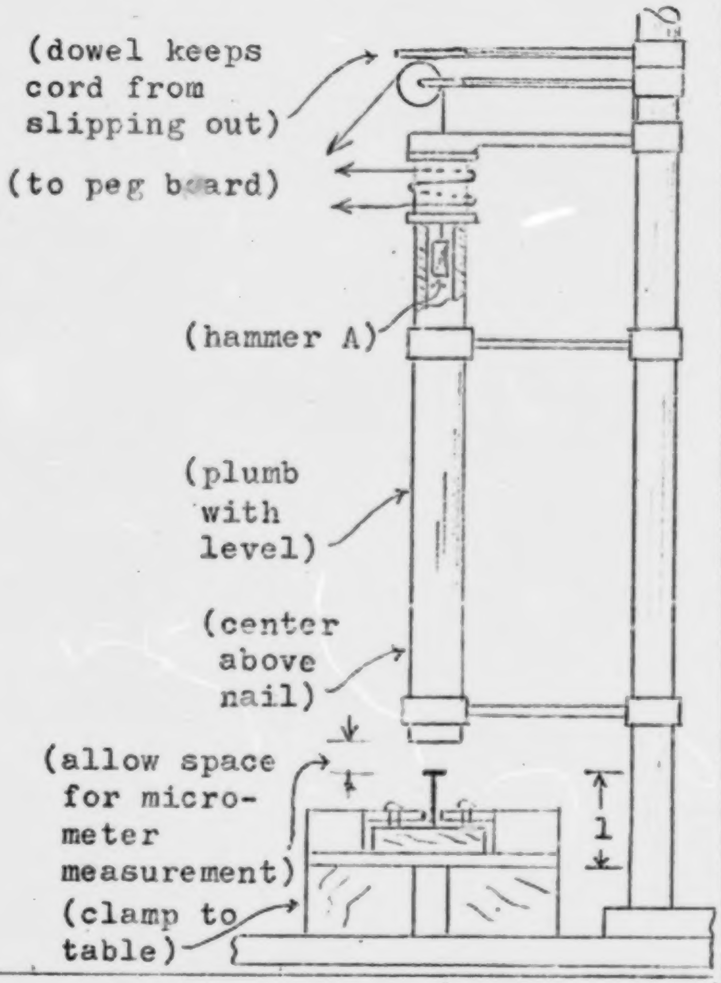
- 3" & 4" micrometers
- 1 & 2 meter tubes
- Electromagnet & arm
- Pulley assembly
- Peg board & leads
- Triple beam balance
- Wooden blocks
- Hammers
- Cord
- Screw driver
- Level
- Nails (2"x #12)
- 2 C clamps
- Block holder

REFERENCES:

1. White, Modern College Physics, pp. 24-8, pp. 46-7

GATHERING THE DATA:

1. Set up "pile driver" as shown.
   a) adjust guide tube so that distance from bottom of hammer to top of nail is 1 meter = s
   b) insert nail 1/4" into wood block (in pre-drilled hole)
   c) with switch on, hammer held at top of guide tube
   d) measure distance l using micrometer
2. Release hammer A by turning switch off. --measure l & determine Δd, the depth which the nail has been driven into the wood.
3. Repeat step #2 for every 4 blows and record data in table:



m Hammer mass (kg)	s Freefall distance (meters)	Blows	Δd Change in nail depth (meters)	Use average of 4 blows to calculate these			
				Δp Change in hammer momentum in striking nail	a Hammer deceleration in striking nail	t Time for hammer and nail to come to rest	f Impact force during collision (nt)

4. Repeat steps #1, 2, and 3 for the other hammer.

he plainly states: 'Hitherto I have not been able to discover the cause...of gravity from phenomena, and I frame no hypothesis...the cause of gravity is what I do not pretend to know...' ".

J. A. Weisheipl, O.P.

PROBLEM: To experimentally examine velocity, energy, momentum, and impulse factors in "pile driving."

APPARATUS:

3" & 4" micrometers
1 & 2 meter tubes
Electromagnet & arm
Pulley assembly
Peg board & leads
Triple beam balance
Wooden blocks
Hammers
Cord
Screw driver
Level
Nails (2"x #12)
2 C clamps
Block holder

REFERENCES:

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pp. 24-8
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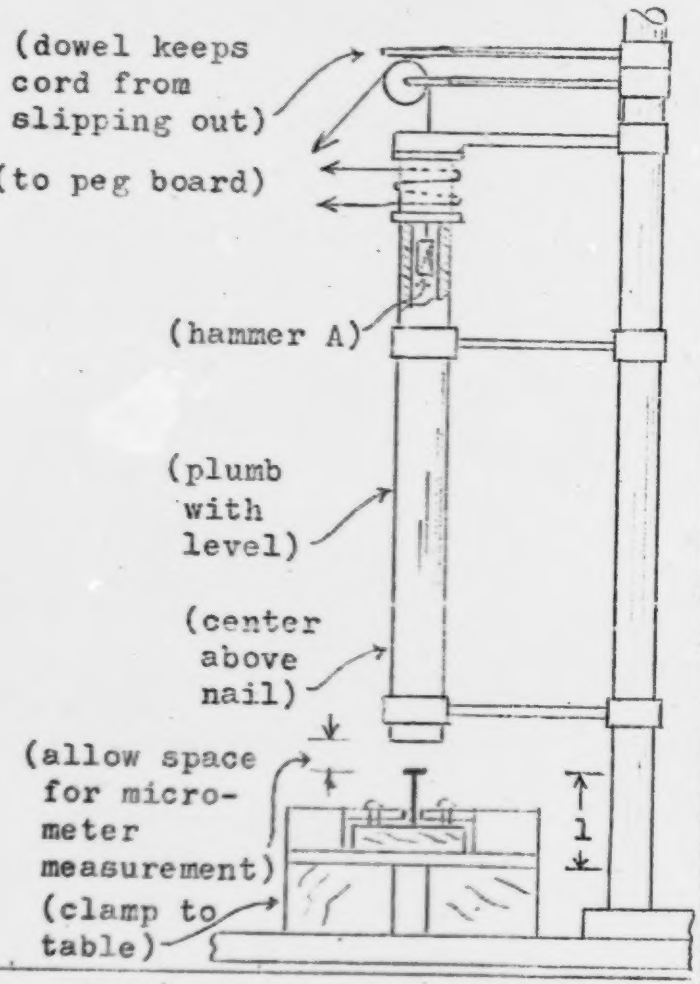


GATHERING THE DATA:

1. Set up "pile driver" as shown.
   a) adjust guide tube so that distance from bottom of hammer to top of nail is 1 meter = s
   b) insert nail 1/4" into wood block (in pre-drilled hole)
   c) with switch on, hammer held at top of guide tube
   d) measure distance l using micrometer
2. Release hammer A by turning switch off. --measure l & determine Δd, the depth which the nail has been driven into the wood.
3. Repeat step #2 for every 4 blows and record data in table:

m Hammer mass (kg)	s Freefall distance (meters)	Blows	Δd Change in nail depth (meters)	Use average of 4 blows to calculate these			
				Δp Change in hammer momentum in striking nail	a Hammer deceleration in striking nail	t Time for hammer and nail to come to rest	f Impact force during collision (nt)

4. Repeat steps #1, 2, and 3 for the other hammer.
5. Repeat steps #1, 2, 3, and 4 for 2 meter drop.

SUMMATION:

1. How does average depth which nail is driven vary with hammer mass?
2. How does average depth which nail is driven vary with hammer fall s?
3. Calculate the hammer's potential energy for each test.
4. Calculate the average work done by each hammer blow.
5. Determine the efficiency of the "pile" driver.
   Detail difficulties.

Station | AVIATION HIGH SCHOOL | Exp.# 48 | APPLIED PHYSICS LABORATORY | Team

> "An engineer is a man who knows a great deal about a very little, and who goes along knowing more and more about less until he knows practically everything about nothing. A salesman, on the other hand, is a man who knows a very little about a great deal, and keeps knowing less and less about more, until he knows practically nothing about everything."
>
> Union Oil Bulletin

PROBLEM: To experimentally determine the factors in spring vibration, to develop an appropriate equation for spring vibration, and to measure mass.

APPARATUS:

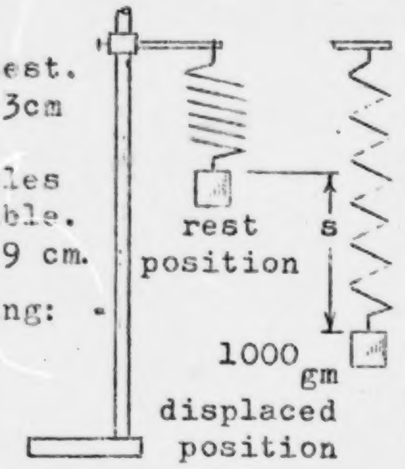
- Stop watch
- 2 iron bases
- 2 extension clamps
- Meter stick
- Rod and holder
- Hooked "wts" 10-500gm
- Slotted "wts" 10-500gm
- Springs
- 1 C clamp
- Masses X,Y,Z

REFERENCES:

1. White, Modern College Physics, p. 175
2. Dull, Modern Physics, pp. 179-80
3. Stollberg, Physics Fund. pp. 237-8
4. Arons, Development of Concepts of Physics, pp. 164-7

GATHERING THE DATA:

1. a) Mount spring A for test.
   b) Displace "weight" s = 3cm and release.
   c) Time 50 complete cycles and record data in table.
   d) Repeat for 6 cm and 9 cm.
2. Repeat step #1 for spring:
   a) B with 100 gm load
   b) C with 20 gm load



(Spring A)

Load	s	t (50)	T(period)
1000 g	3 cm		
1000 g	6 cm		
1000 g	9 cm		

(Spring B)

Load	s	t (50)	T (period)
100 g	9 cm		

3. a) Remount spring A.
   b) Apply 100 gm load--displace and time 50 complete cycles.
   c) Repeat for 400, 900, and 1600 gm loads. --enter results in table:
   d) Plot graphs:

Mass	t (50)	T (period)	T^2
100gm			
1600gm			

SUMMATION:

1. According to experimental data:
   a) What effect does initial displacement have on spring period?
   b) What is the relation between T^2 and m?
2. Consider object rotating at constant speed.

by centripetal acceleration:

$$a = \frac{v^2}{} = \frac{\left(\frac{2\pi R}{T}\right)^2}{} = \frac{4\pi^2 R}{}$$

everything."

Union Oil Bulletin

PROBLEM: To experimentally determine the factors in spring vibration, to develop an appropriate equation for spring vibration, and to measure mass.

APPARATUS:

Stop watch	Springs
2 iron bases	1 C clamp
2 extension clamps	Masses X,Y,Z
Meter stick	
Rod and holder	
Hooked "wts" 10-500gm	
Slotted "wts" 10-500gm	

REFERENCES:

1. White, Modern College Physics, p. 175
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GATHERING THE DATA:

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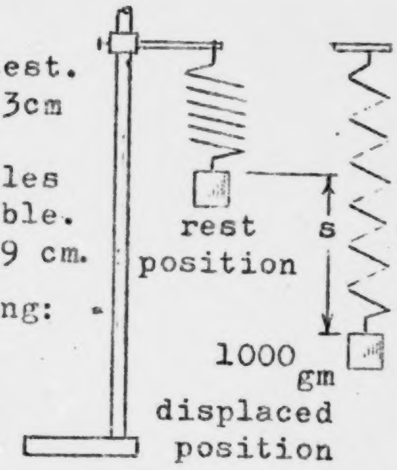


(Spring A)

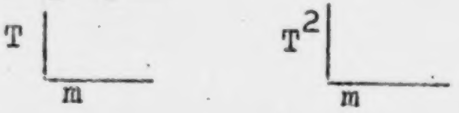
Load	s	t (50)	T(period)
1000 g	3 cm		
1000 g	6 cm		
1000 g	9 cm		

(Spring B)

Load	s	t (50)	T (period)
100 g	9 cm		

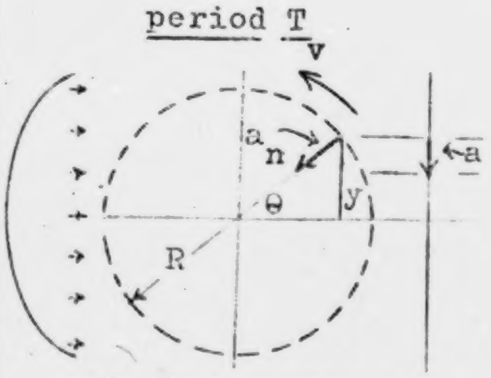
3. a) Remount spring A.
   b) Apply 100 gm load--displace and time 50 complete cycles.
   c) Repeat for 400, 900, and 1600 gm loads. --enter results in table:
   d) Plot graphs:

Mass	t (50)	T (period)	T^2
100gm			
1600gm			



SUMMATION:

1. According to experimental data:
   a) What effect does initial displacement have on spring period?
   b) What is the relation between T^2 and m?
2. Consider object rotating at constant speed.



projected motion SHM
since a ∝ y

by centripetal acceleration:

$$a_n = \frac{v^2}{R} = \frac{\left(\frac{2\pi R}{T}\right)^2}{R} = \frac{4\pi^2 R}{T^2}$$

$$a = a_n \sin\theta = a_n \frac{y}{R} = \frac{4\pi^2 y}{T^2}$$

thus $T = 2\pi\sqrt{\frac{y}{a}}$

but for spring: F = ky ∵ SHM

$$\therefore\ T = 2\pi\sqrt{\frac{y}{F/m}} = 2\pi\sqrt{\frac{m}{F/y}} = 2\pi\sqrt{\frac{m}{k}}$$

which → $T^2 \propto m$ with constant of proportionality: $\frac{4\pi^2}{k}$

Compare with experimental results.

3. Using springs, show how masses X,Y,& Z can be measured in outer space.

Station 143 Exp.# 49 Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "An earth satellite can transmit more positional information in one day than all the data Tycho Brahe collected about the planets in many years."
>
> Albert V. Baez

PROBLEM: To graphically derive the inverse square law of gravitation for a satellite pursuing an elliptical orbit, and obeying Newton's 2nd Law and Kepler's 2nd Law.

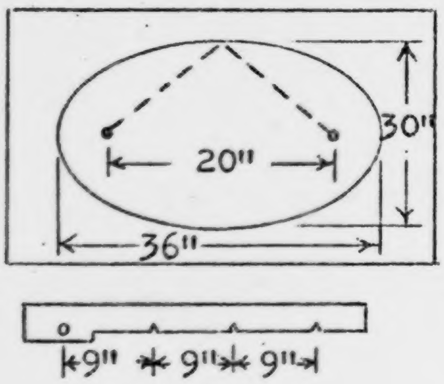
APPARATUS:

Drawing board
Black thread
1/16" pellets
Special pen
Mirror
Cord & pins
White paper
Scissor bars

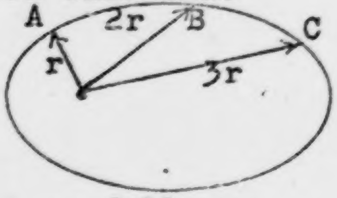
REFERENCES:

1. Baez, Am. Journal of Physics, pp. 254-9
2. Feynman, Lectures on Physics, pp. 7-1 to 7-3

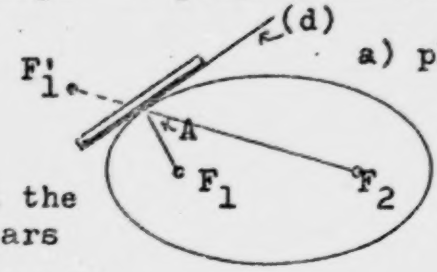
GATHERING THE DATA:



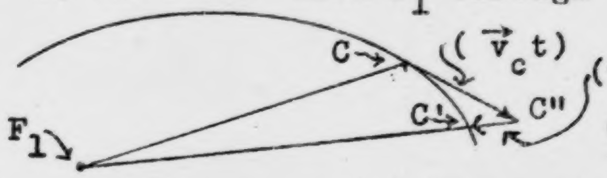
1. Using cord and ball point pen draw large ellipse.
   a) tape paper to board.
   b) fasten 36" of cord length between foci and test to see that length selected will make 30" x 36" ellipse.
   c) draw ellipse.



2. Locate points A, B, and C using notched ruler.
3. Draw tangent to ellipse at point A as follows:



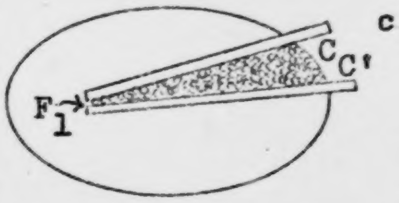
   a) place pin at point A.
   b) pull string tautly over points F_1, A, and F_2.
   c) adjust mirror against pin until the image of F_1A appears to make a straight line extension of F_2A.
   d) draw tangent line along mirror's edge.
   e) repeat for points B and C.
4. a) Select point C' (for convenience approx. 3½" away from C) to which satellite moves from C in arbitrary time t. (Assume motion clockwise)
   b) Draw line from F_1 through C' to tangent.



(vector C"C' directed toward focus F_1)

$$C''C' = \frac{1}{2}\vec{a}_c t^2$$

(C"C' is the distance satellite must fall toward focus--center of earth--in time t in order to stay in elliptic orbit)



   c) Adjust metal bars from F_1 to C & F_1 to C' and fill area enclosed by bars and CC' portion of ellipse with 1/16" pellets--tilt board facilitating manipulation of pellets).
5. Using Kepler's 2nd Law:
   a) Determine corresponding points B' & B" for B by placing one metal bar along F_1B and the other such that the area enclosed by the two bars and the BB' portion of the ellipse accurately accommodates the same number of pellets used in step #4.

PROBLEM: To graphically derive the inverse square law of gravitation for a satellite pursuing an elliptical orbit, and obeying Newton's 2nd Law and Kepler's 2nd Law.

APPARATUS:

Drawing board
Black thread
1/16" pellets
Special pen
Mirror
Cord & pins
White paper
Scissor bars

REFERENCES:

1. Baez, Am. Journal of Physics, pp. 254-9
2. Feynman, Lectures on Physics, pp. 7-1 to 7-3

GATHERING THE DATA:

1. Using cord and ball point pen draw large ellipse.
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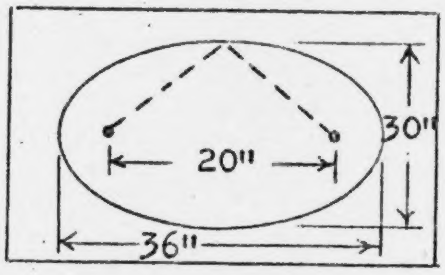
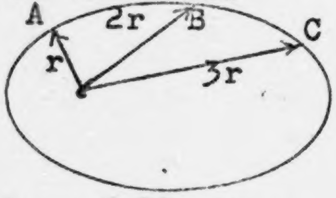
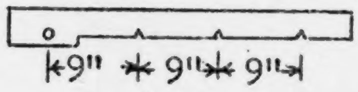




2. Locate points A, B, and C using notched ruler.



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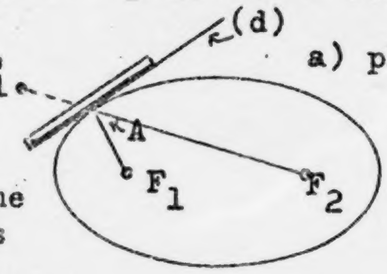

a) place pin at point A.
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c) adjust mirror against pin until the image of F_1A appears to make a straight line extension of F_2A.
d) draw tangent line along mirror's edge.
e) repeat for points B and C.

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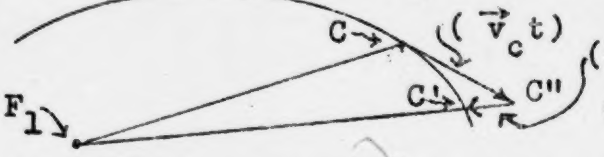
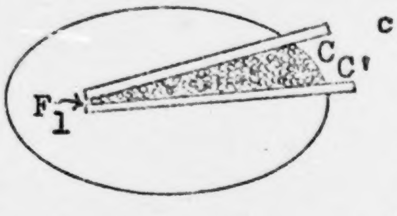


(vector C"C' directed toward focus F_1)

$C''C' = \frac{1}{2}\vec{a}_c t^2$ (C"C' is the distance satellite must fall toward focus--center of earth--in time t in order to stay in elliptic orbit)



   c) Adjust metal bars from F_1 to C & F_1 to C' and fill area enclosed by bars and CC' portion of ellipse with 1/16" pellets--tilt board facilitating manipulation of pellets).

5. Using Kepler's 2nd Law:
   a) Determine corresponding points B' & B" for B by placing one metal bar along F_1B and the other such that the area enclosed by the two bars and the BB' portion of the ellipse accurately accommodates the same number of pellets used in step #4.
   b) Draw vectors $\vec{v}_B t$ and $\frac{1}{2}\vec{a}_B t^2$

6. Repeat step #5 for points A' and A" and vectors $\vec{v}_A t$ and $\frac{1}{2}\vec{a}_A t^2$

SUMMATION:

1. Verify that: $\frac{1}{2}\vec{a}_C t^2 < \frac{1}{2}\vec{a}_B t^2 < \frac{1}{2}\vec{a}_A t^2$ --since t = for each, these vectors are proportional to accelerations: $\vec{a}_{C'}$, $\vec{a}_B$, and $\vec{a}_A$
2. Using Newton's 2nd Law, show that these vectors are also proportional to the corresponding gravitational forces at points A, B, and C. Thus force C < force B < force A
3. According to experimental data, since the distance from focus F_1 to C is double that to B and triple that to A:
   a) What effect does distance have on the gravitational forces?
   b) Generalize.

Station ⬡ AVIATION HIGH SCHOOL Exp.# 50 APPLIED PHYSICS LABORATORY Team ○

> "...the theory of eccentrics and epicycles is considered as established, because thereby the sensible appearances of celestial movements can be explained...(yet) the phenomena of celestial bodies may perhaps be saved in some other way not yet known to man."
>
> Thomas Aquinas
>
> "The popular belief that Copernicus' heliocentric system constitutes a significant simplification of the Ptolemaic system is obviously wrong. ...the Copernican models themselves require about twice as many circles as the Ptolemaic models and are far less elegant and adaptable."
>
> Otto Neugebauer

PROBLEM: To locate satellites in space

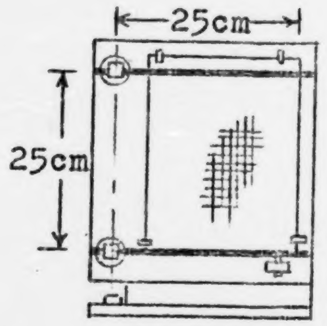
APPARATUS:

Range finder	Meter stick & slotted card
Satellites	Graph paper & level

REFERENCES:

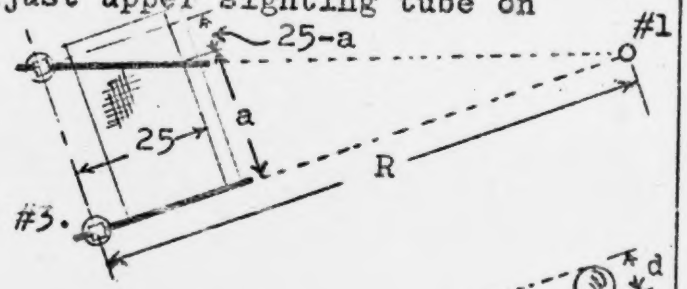
1. Thomas, Calculus and Analytic Geometry, pp. 603-8

GATHERING THE DATA:

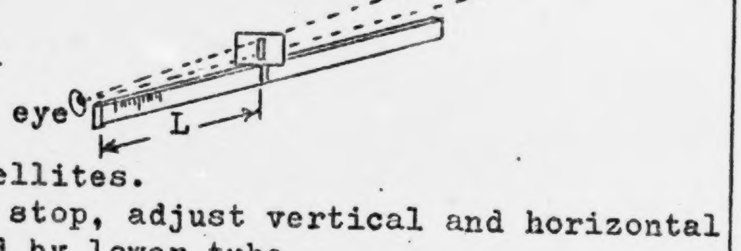


1. Determine range of satellite #1.
   - a) with vertical swivel set at zero, set lower sighting tube level and against stop.
   - b) tape graph paper in place, parallel to lower sighting tube & with reference line set 25cm from pivot.
   - c) keeping lower sighting tube against stop, adjust vertical and horizontal swivels until satellite #1 is accurately centered in the lower sighting tube.
   - d) lock both swivels in place and then adjust upper sighting tube on satellite #1.
   - e) calculate distance to satellite #1:

$$R = \frac{(25)^2}{25-a}$$



   - f) repeat above steps for satellites #2 & #3.
2. Determine the diameter of satellite #1:
   - a) with meter stick aimed at satellite, adjust L until satellite just fills slot height--top to bottom.
   - b) calculate satellite diameter $d = \frac{hR}{L}$
   - c) repeat for satellites #2 & #3.

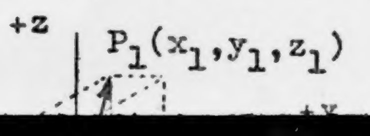


3. Determine the distances between the satellites.
   - a) keeping lower sighting tube against stop, adjust vertical and horizontal swivels until satellite #1 is sighted by lower tube.

     Record: horizontal swivel angle θ
     vertical swivel angle ϕ
   - b) repeat a for satellites #2 and #3.
   - c) determine the magnitudes of the components of satellite #1's position vector $\overrightarrow{OP_1} = [\vec{x}_1, \vec{y}_1, \vec{z}_1]$

$$|\vec{z}_1| = P'_1P_1 = |\overrightarrow{OP_1}| \sin\phi$$

$$OP'_1 = |\overrightarrow{OP_1}| \cos\phi$$



Thomas Aquinas

> "The popular belief that Copernicus' heliocentric system constitutes a significant simplification of the Ptolemaic system is obviously wrong. ...the Copernican models themselves require about twice as many circles as the Ptolemaic models and are far less elegant and adaptable."
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> Otto Neugebauer

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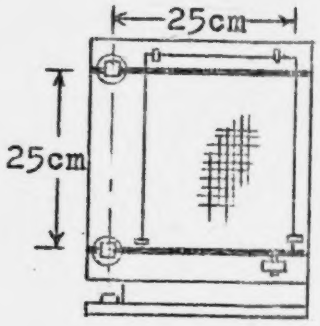

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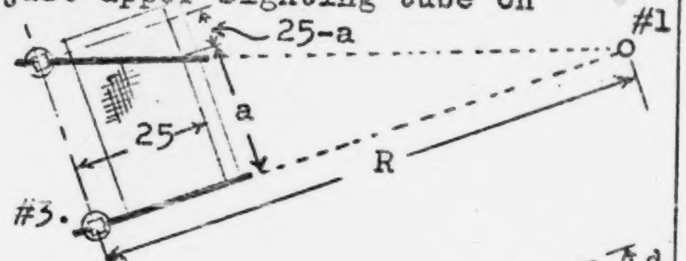
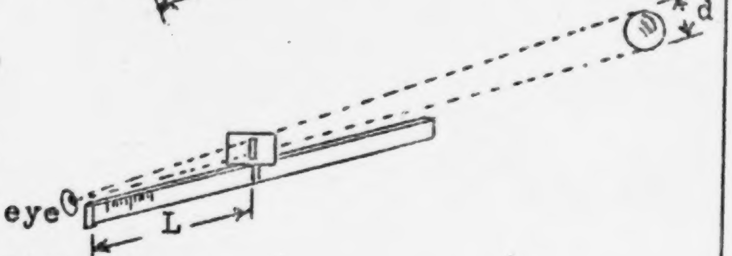


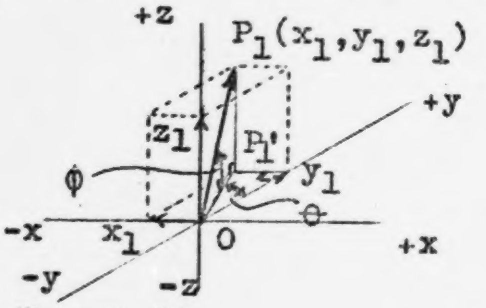
   f) repeat above steps for satellites #2 & #3.

2. Determine the diameter of satellite #1:
   a) with meter stick aimed at satellite, adjust L until satellite just fills slot height--top to bottom.
   b) calculate satellite diameter $d = \frac{hR}{L}$
   c) repeat for satellites #2 & #3.



3. Determine the distances between the satellites.
   a) keeping lower sighting tube against stop, adjust vertical and horizontal swivels until satellite #1 is sighted by lower tube.
      Record: horizontal swivel angle θ
      vertical swivel angle ϕ
   b) repeat a for satellites #2 and #3.
   c) determine the magnitudes of the components of satellite #1's position vector $\overrightarrow{OP_1} = [\vec{x}_1, \vec{y}_1, \vec{z}_1]$

$$|\vec{z}_1| = P'_1P_1 = |\overrightarrow{OP_1}| \sin\phi$$
$$OP'_1 = |\overrightarrow{OP_1}| \cos\phi$$
$$|\vec{y}_1| = OP'_1 \cos\theta = |\overrightarrow{OP_1}| \cos\phi \cos\theta$$
$$|\vec{x}_1| = OP'_1 \sin\theta = |\overrightarrow{OP_1}| \cos\phi \sin\theta$$



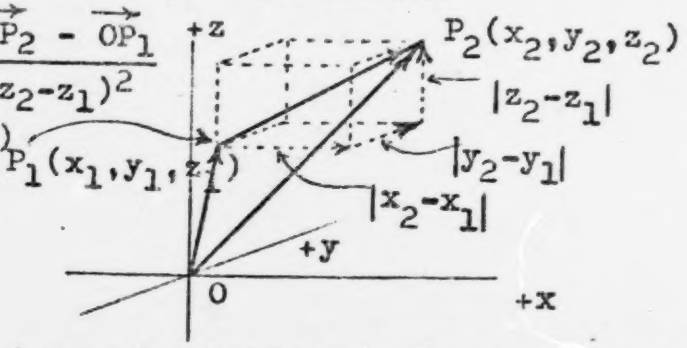
   d) repeat c for position vectors $\overline{OP_2}$ & $\overline{OP_3}$
   e) determine distance $|\overline{P_1P_2}|$ between satellites #1 and #2.

$$\overrightarrow{OP_1} + \overrightarrow{P_1P_2} = \overrightarrow{OP_2} \longrightarrow \overrightarrow{P_1P_2} = \overrightarrow{OP_2} - \overrightarrow{OP_1}$$

or $|\overrightarrow{P_1P_2}| = \sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2}$

(obey rules for signed values)

   f) repeat e for satellites #1 & #3 and #2 & #3.



SUMMATION:

1. Completely determine the position vectors of satellites #2 and #3 with respect to satellite #1.

Station

AVIATION HIGH SCHOOL

Exp.# 51

APPLIED PHYSICS LABORATORY

Team

> "...the science of flight, or aerodynamics has grown out of the older science of hydrodynamics; both deal with the special properties of a fluid, whether water or air; ... How the fish or dolphin swims and how the bird flies, are up to a certain point analogous problems; and stream-lining plays an essential part in both ... the bird is much heavier than air, and the fish has much the same density as water, so that the problem of keeping afloat or aloft is negligible in the one and all important in the other."
>
> D'Arcy Wentworth Thompson

PROBLEM: To experimentally relate shape, drag, and wind velocity.

APPARATUS:

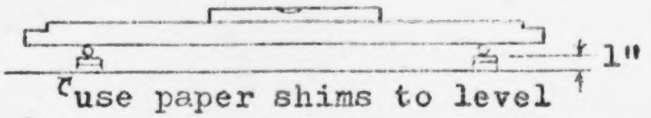
- Wind generator
- Squeeze bottle
- Pitot tube
- Level
- 1mg--50gm set
- Harris Lift & Drag Balance
- Manometer & calibrated meter stick

REFERENCES:

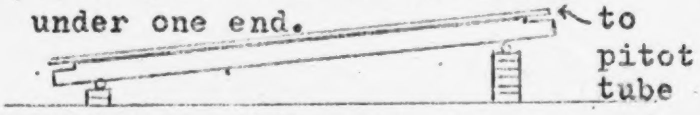
1. Rogers, *Physics for the Inquiring Mind*, pp. 156-7, 165-7

GATHERING THE DATA:

1. Set up manometer for measuring wind speed.
   a) Level manometer.
   b) Add additional 2" of blocks under one end.



use paper shims to level (keep pressed against angle supports)

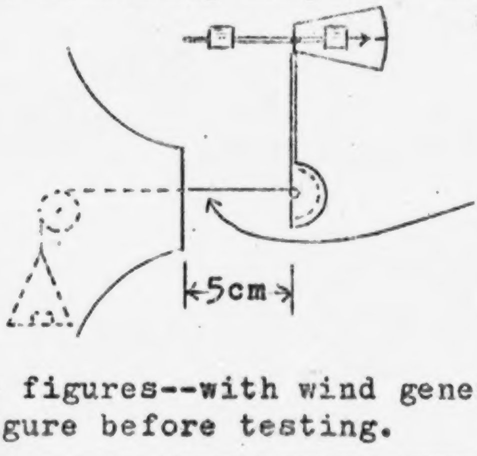


   c) Carefully half fill manometer with water--avoid air bubbles.

2. a) Measure air speeds of 5cm nozzle for speed settings #1,2,3,4,& 5. --place pitot tube at center of nozzle & 5cm in front of it.
   b) Repeat for 10cm nozzle--record in table.

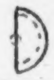
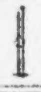
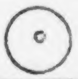
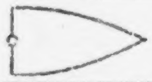
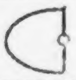
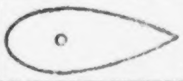
Nozzle	Speed	Air speed (ft/sec)
5 cm	1	
5 cm	5	

3. Set up Harris Balance for measuring drag (see mfg. instructions).
   a) mount cup at center of 5cm nozzle with supporting rod 5cm from nozzle face.
   b) with cup in place, adjust screw wts. until pointer rests at zero
   c) operate generator at #1 & add wts. to pan until pointer is restored to position of balance



(keep cord horizontal)

4. Repeat step #3 for other figures--with wind generator off, adjust screw wts. for balance for each figure before testing.

#	Wind speed (ft/sec)						
1		gm	gm	gm	gm	gm	gm
5		gm	gm	gm	gm	gm	gm

5. Plot graphs:

drag

(use colors to differentiate figures)

> and stream-lining plays an essential part in both ... the bird is much heavier than air, and the fish has much the same density as water, so that the problem of keeping afloat or aloft is negligible in the one and all important in the other."
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Pitot tube
Level
1mg--50gm set
Harris Lift & Drag Balance
Manometer & calibrated meter stick

REFERENCES:

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165-7

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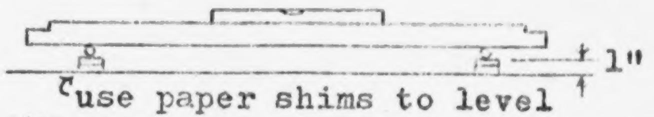
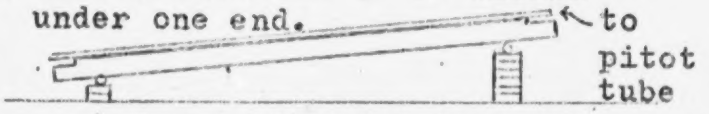


use paper shims to level
(keep pressed against angle supports)

   b) Add additional 2" of blocks under one end.



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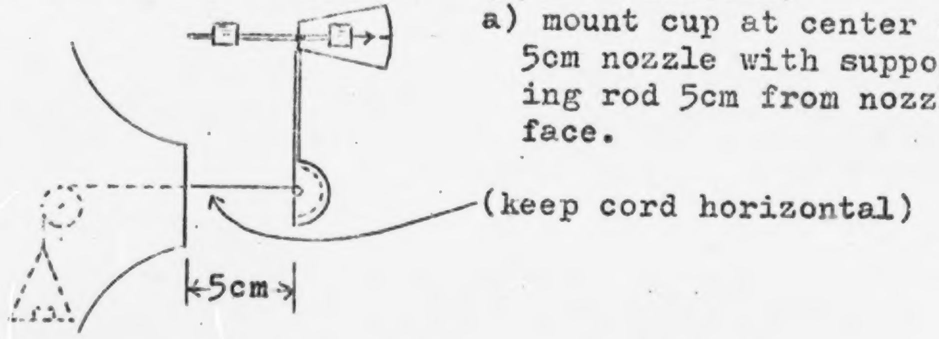

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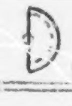
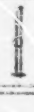
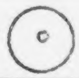
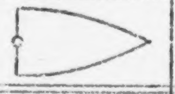
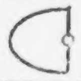
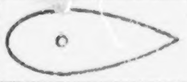
#	Wind speed (ft/sec)						
1		gm	gm	gm	gm	gm	gm
5		gm	gm	gm	gm	gm	gm

5. Plot graphs:

(use colors to differentiate figures)

6. Repeat steps #3, 4, and 5 for 10cm. nozzle.

SUMMATION:

1. Quantitatively compare the measured drags.
2. Which figure has the least drag? Explain.
3. In general, how does drag vary with air speed?

Station | Exp.# 52 | Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "A bird is an instrument working according to mathematical law, which instrument it is within the capacity of man to reproduce with all its movements."
>
> Leonardo DaVinci

PROBLEM: To experimentally relate lift, angle of attack, and relative wind speed. To measure the absolute pressure at points on top of an airfoil.

APPARATUS:

Wind generator
Squeeze bottle
Pitot tube
Level
1mg-50gm set
Barometer
Harris Lift and Drag Balance
Manometer & calibrated meter sticks

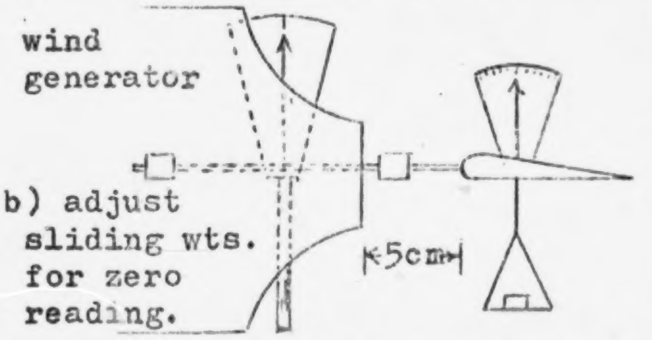
REFERENCES:

1. Rogers, Physics for the Inquiring Mind, p. 165
2. Halliday & Resnick, Physics, pp. 380-1
3. White, Modern College Physics, pp. 205-6

GATHERING THE DATA:

1. Measure air speeds for 18cm. nozzle.
   a) Set manometer for 2" rise/40" length.
   b) Place pitot tube at center of nozzle and 5cm. in front of it.
   c) Record measurements in table.

2. Measure lift using Harris Balance--see mfg. instructions.
   a) mount air foil on Harris balance--at center of 18cm. nozzle and 5cm. in front of it.
   c) level bottom surface of wing and set air foil shaft pointer for zero angle reading.
   d) operate wind generator at speed #1 and add wts. in pan until balance is restored.
   e) repeat for speeds #2,3,4,& 5.
   --record data in table.

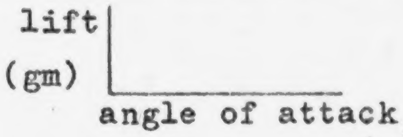


b) adjust sliding wts. for zero reading.

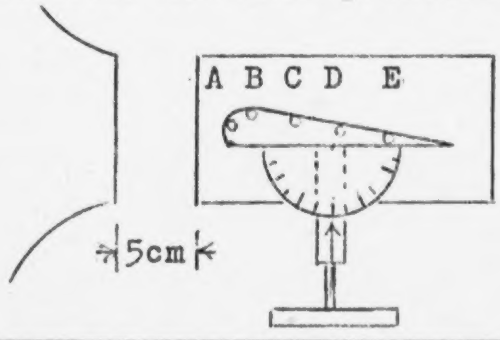
3. Repeat step #2 for angle of attack = 2°, 4°, 6°, ...

#	Wind speed(ft/sec)	0°	2°	4°	- - - - - - - - - -	20°
1		gm	gm	gm		gm
5		gm	gm	gm		gm

4. Plot graph: (use colors to differentiate speeds)



5. Measure absolute pressures atop airfoil.
   a) set airfoil at center of 18cm nozzle & 5cm in front of it at 0° angle of attack.
   b) connect manometer to hole A & measure absolute pressure using calibrated meter stick.
   c) repeat b for 5°, 10°, ...
   d) repeat b & c for holes B, C, D, and E.



#	Wind speed(ft/sec)	0°	5°	10°	- - - - - - - -	etc.
1		psi	psi	psi		psi

PROBLEM: To experimentally relate lift, angle of attack, and relative wind speed. To measure the absolute pressure at points on top of an airfoil.

APPARATUS:

Wind generator
Pitot tube
1mg-50gm set
Squeeze bottle
Level
Barometer
Harris Lift and Drag Balance
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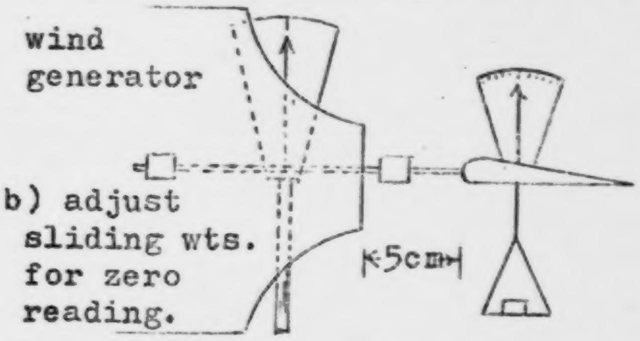


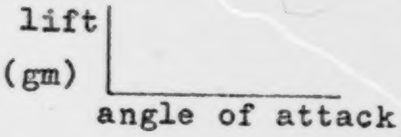
b) adjust sliding wts. for zero reading.

a) mount air foil on Harris balance--at center of 18cm. nozzle and 5cm. in front of it.
c) level bottom surface of wing and set air foil shaft pointer for zero angle reading.
d) operate wind generator at speed #1 and add wts. in pan until balance is restored.
e) repeat for speeds #2,3,4,& 5.
--record data in table.

3. Repeat step #2 for angle of attack - 2°, 4°, 6°, ...

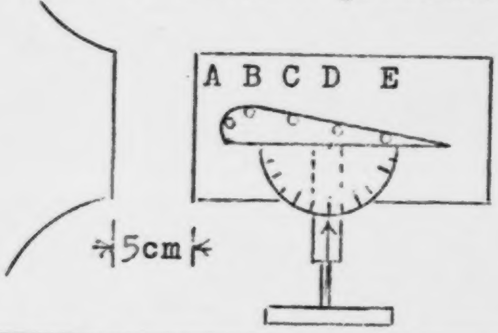
#	Wind speed(ft/sec)	0°	2°	4°	- - - - - - - - - -	20°
1		gm	gm	gm		gm
5		gm	gm	gm		gm

4. Plot graph:



(use colors to differentiate speeds)

5. Measure absolute pressures atop airfoil.



a) set airfoil at center of 18cm nozzle & 5cm in front of it at 0° angle of attack.
b) connect manometer to hole A & measure absolute pressure using calibrated meter stick.
c) repeat b for 5°, 10°, ...
d) repeat b & c for holes B, C, D, and E.

#	Wind speed(ft/sec)	0°	5°	10°	- - - - - - - -	etc.
1		psi	psi	psi		psi
5		psi	psi	psi		psi

SUMMATION:

1. a) At which angle of attack and windspeed is lift maximum?
   b) What happens when this angle of attack is exceeded?
   c) How does lift vary with relative wind speed?
2. Compare results with those gathered from the venturi tube. Explain lift.
3. Explain how calibrated meter sticks and manometer yield speed and pressure data.

Station

Exp. # 53

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

Team

> "Although this may seem a paradox, all exact science is dominated by the idea of approximation."
>
> , Bertrand Russell

PROBLEM: To measure resistance with an ohmmeter, interpret the resistor color code and become familiar with tolerances.

APPARATUS:

Weston ohmmeter	multitester
Circuit board #8	battery tester
Master resistances	template
Jeweler's screwdriver	crayons
Resistor arrays A, B, & C	

REFERENCES:

1. Philco, Basic Concepts Vol. I, pp. 40-42, 52-54
2. Gerrish, Electricity & Electronics, p. 306
3. USN Aviation Electrician's Mate, pp. 6-3,4, 15-6,7

GATHERING THE DATA:

1. a) Zero the Weston ohmmeter and check it for accuracy against the masters.
   b) Using Weston ohmmeter, measure the resistors on circuit board #8, list in table, and select appropriate color code.

Resistor	Ohms	Color Code
R11		-[||||]-
R52		-[||||]-
R53		-[||||]-

← use template to draw resistors

use crayons to color

2. Zero multitester and measure resistors on Array A. (it will be necessary to select the proper range in checking each resistor, making sure that the reading occurs on the dial section leading to greatest accuracy--zero meter frequently)
3. Repeat for array B.

Resistor	Ohms	Color Code
A1		-[||||]-
A2		-[||||]-
A15		-[||||]-

4. Determine resistor sizes by color code, check against meter, and calculate the % difference.

Resistor	Given Colors	R_c (color)	R_m (meter)	$R_d = R_c - R_m$	% diff. = R_d/R_c
C1	-[||||]-				
C2	-[||||]-				
C15	-[||||]-				

SUMMATION:

1. List the steps and precautions that must

APPARATUS:		REFERENCES:
Weston ohmmeter	multitester	1. Philco, Basic Concepts Vol. I, pp. 40-42, 52-54
Circuit board #8	battery tester	2. Gerrish, Electricity & Electronics, p. 306
Master resistances	template	3. USN Aviation Electrician's Mate, pp. 6-3,4, 15-6,7
Jeweler's screwdriver	crayons	
Resistor arrays A,B,& C		

GATHERING THE DATA:

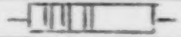
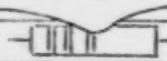
1. a) Zero the Weston ohmmeter and check it for accuracy against the masters.
   b) Using Weston ohmmeter, measure the resistors on circuit board #8, list in table, and select appropriate color code.

Resistor	Ohms	Color Code
R11		
R52		
R53		

←use template to draw resistors
use crayons to color

2. Zero multitester and measure resistors on Array A.
   (it will be necessary to select the proper range in checking each resistor, making sure that the reading occurs on the dial section leading to greatest accuracy--zero meter frequently)

3. Repeat for array B.

Resistor	Ohms	Color Code
A1		
A2		
A15		

4. Determine resistor sizes by color code, check against meter, and calculate the % difference.

Resistor	Given Colors	R_c (color)	R_m (meter)	$R_d = R_c - R_m$	% diff. = R_d/R_c
C1					
C2					
C15					

SUMMATION:

1. List the steps and precautions that must be observed in using an ohmmeter.
2. Why is it not sufficient to just zero an ohmmeter?
3. What supplies electricity for the ohmmeter?
4. In what respect does an ohmmeter's scale differ from that of a typical electrical meter?
5. Which part of an ohmmeter's scale is most easily read? Why?
6. How can you tell when an ohmmeter needs a battery replacement?
7. Carefully open the back of the Weston meter, remove the battery, check with 1 volt bulb, observe brightness, and replace observing polarity. What does brightness indicate?
8. Check circuit board rheostat for max. & min. resistance. Record values.
9. Categorize the resistors on array C according to ± 10%, ± 5%, & ± [illegible] tolerances.

Station

Exp.# 54

Team

AVIATION HIGH SCHOOL

APPLIED PHYSICS LABORATORY

> "Genius is one percent inspiration and ninety-nine percent perspiration."
>
> Thomas A. Edison

PROBLEM: To hook-up series, parallel, and series-parallel circuits. To measure and to calculate resistance in electrical circuits.

APPARATUS:

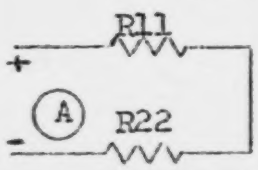
Weston Ohmmeter
Circuit Board #1
30 clip leads
100 & 200 ohm master resistances

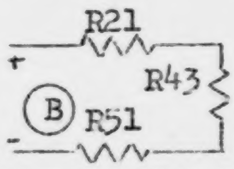
REFERENCES:

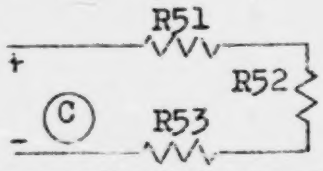
1. Philco, Basic Concepts Vol. I, pp. 41-2
2. USN Aviation Elec. Mate's Manual pp. 6-3; 9-4
3. Taffel, Visualized Physics, pp.257-60

GATHERING THE DATA:

1. Zero meter. Check meter accuracy against master resistances. (Repeat frequently!)
2. Wire the following circuits. Measure the individual and total resistances. Record readings on sketches.




R21
+
R43
B
R51
-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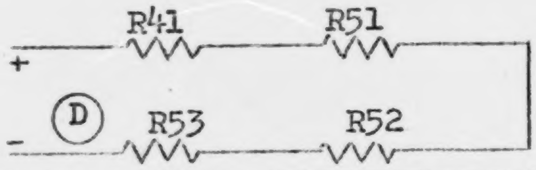
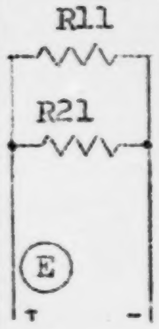
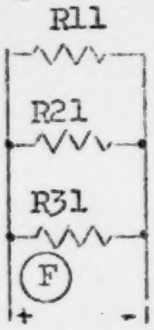
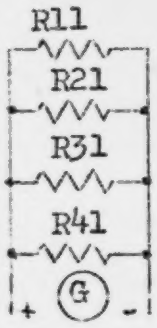
+
R52
C
R53
-


R41
R51
+
D
R53
R52
-

Check individual resistances & resistances between letters before completing wiring.




R11
R21
R31
F
+
-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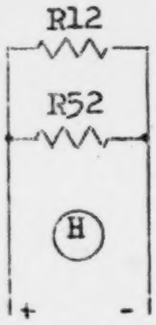
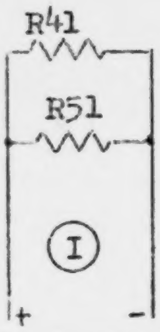
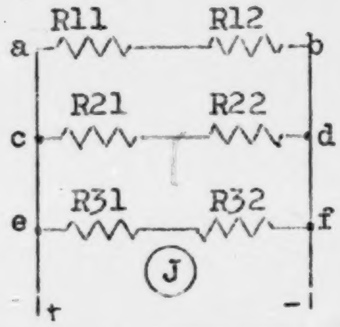
R21
R31
R41
G
+
-



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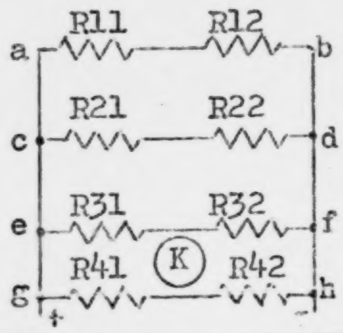
R21
R22
d
e
R31
R32
f
J
+
-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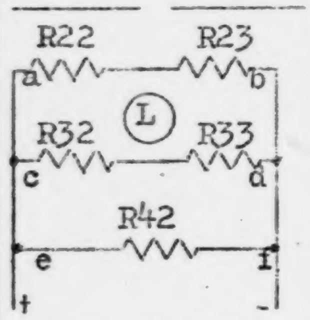
f
g
R41
K
R42
h
+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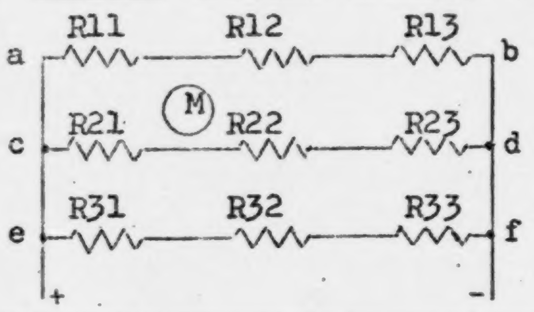
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R33
f
+
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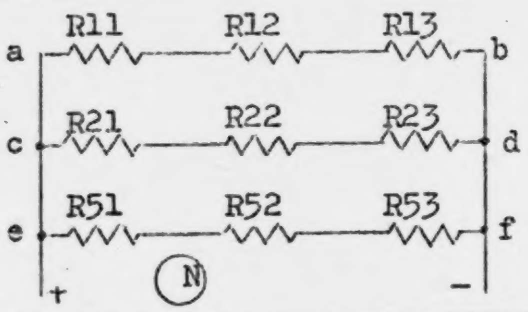
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R52
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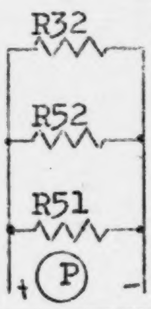
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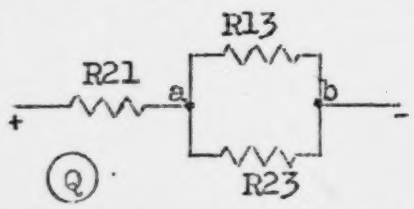
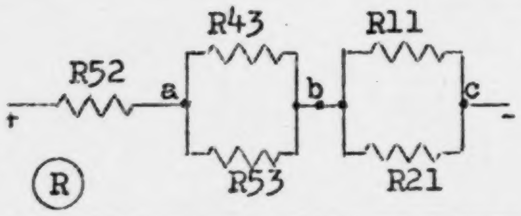
R51
+
P
-


R21
+
a
R13
b
-
R23
Q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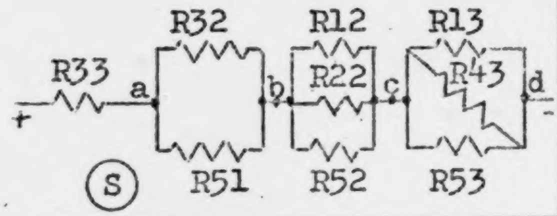
b
R11
c
-
R53
R21
R


R33
+
a
R32
b
R12
R22
c
R13
R43
d
-
R51
R52
R53
S

SUMMATION:

1. What general rule regarding series resistance has experiment revealed?
2. Apply $R_T = \frac{R_i}{N}$ to circuits E, F, G and to branches of circuits J, K, M.

PROBLEM: To hook-up series, parallel, and series-parallel circuits. To measure and to calculate resistance in electrical circuits.

APPARATUS:

Weston Ohmmeter
Circuit Board #1
30 clip leads
100 & 200 ohm master resistances

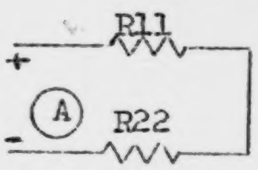
REFERENCES:

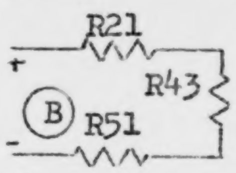
1. Philco, Basic Concepts Vol. I, pp. 41-2
2. USN Aviation Elec. Mate's Manual pp. 6-3; 9-4
3. Taffel, Visualized Physics, pp.257-60

GATHERING THE DATA:

1. Zero meter. Check meter accuracy against master resistances. (Repeat frequently!)

2. Wire the following circuits. Measure the individual and total resistances. Record readings on sketches.

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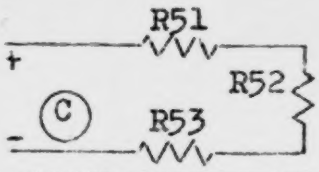
R43
B
R51
-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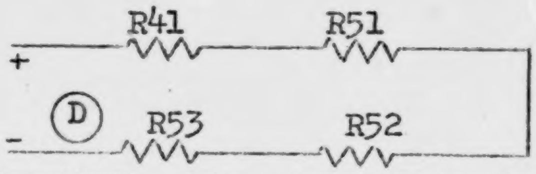
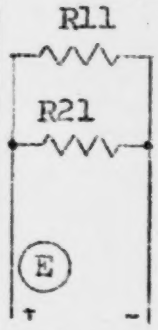
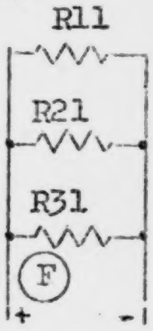
+
R52
C
R53
-


R41
R51
+
D
R53
R52
-

Check individual resistances & resistances between letters before completing wiring.

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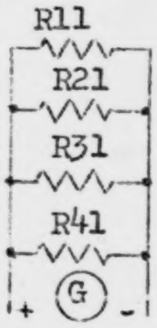
R21
R31
F
+
-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R31
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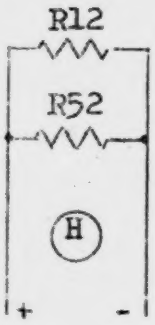
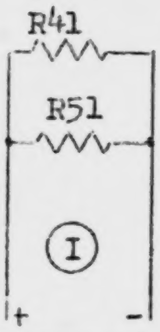
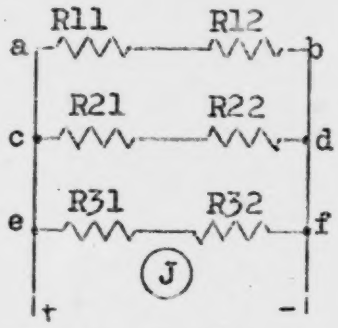
G
+
-



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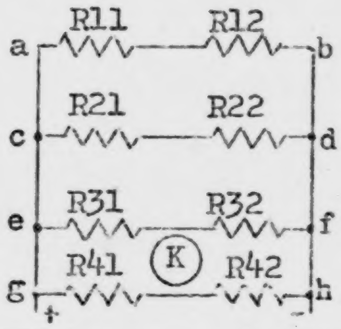
R22
d
e
R31
R32
f
J
+
-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K
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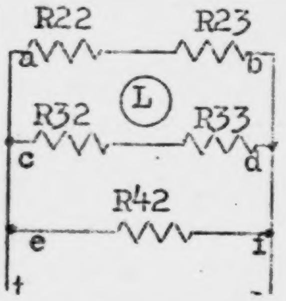
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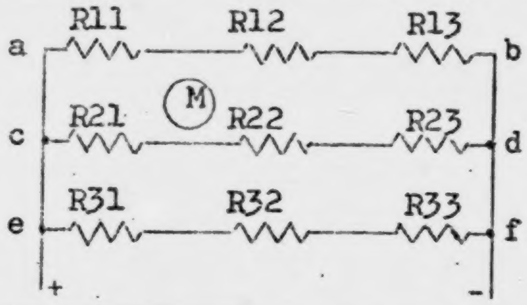
R32
L
R33
c
d
R42
e
f
+
-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M
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R33
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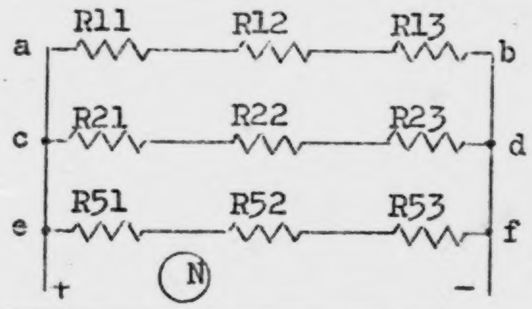
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R52
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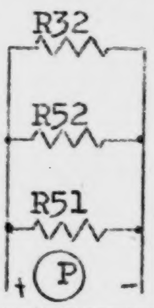
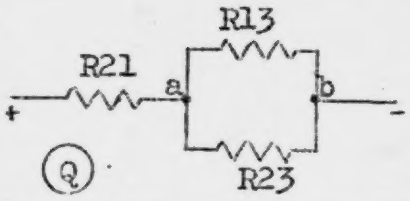
f
N
+
-


R32
R52
R51
+
P
-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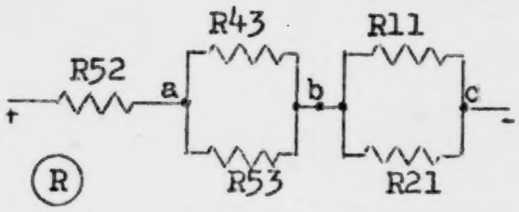
R21
a
b
+
-
R23
Q


R43
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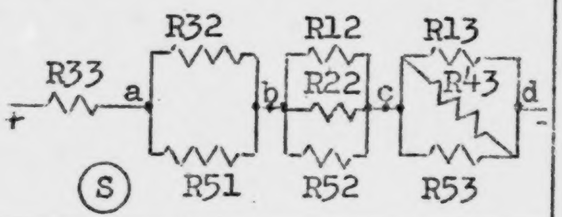
R52
a
b
c
+
-
R53
R21
R


R32
R12
R13
R33
a
b
R22
c
R43
d
+
-
S
R51
R52
R53

SUMMATION:

1. What general rule regarding series resistance has experiment revealed?
2. Apply $RT = \frac{Ri}{N}$ to circuits E, F, G and to branches of circuits J, K, M.

   Apply $RT = \frac{R' \times R''}{R' + R''}$ to circuits E, H, I.

   Do the mathematical results agree with the experimental results?
3. Apply $\frac{1}{RT} = \frac{1}{R'} + \frac{1}{R''} + \frac{1}{R'''}$ to the branches of circuit N. Show all calculations.
4. Show how the total resistances of circuits Q, R, & S are calculated. Do the mathematical results agree with the experimental results?
5. Show how master resistors can be wired to make a 50 ohm standard.
6. Using as few resistors as possible, sketch and check circuits having the following resistances:

   I. 70 ohms II. 25 ohms III. 50 ohms IV. 5 ohms

Station

Exp.# 55

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Any definition in physics rightly understood is an operation, something done with the hands.... The proper way to define, or set boundaries to a cow pasture is to build a fence around it."
>
> William S. Franklin

PROBLEM: To experimentally examine the relationship between voltage and current.

APPARATUS:

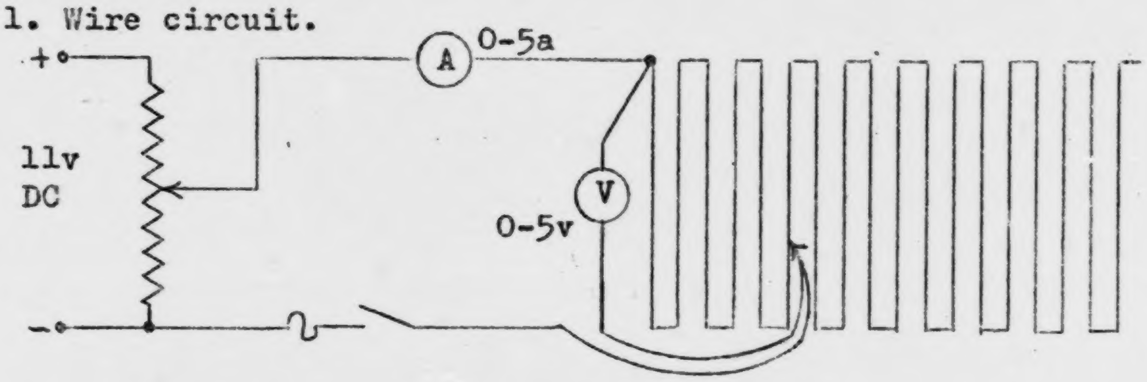
0-5a ammeter
0-15v Weston voltmeter
Fuse and fuse holder
Peg board and wire
SPST switch
10 clip leads
2 microgator clip leads
Potentiometer

REFERENCES:

1. Turner, Basic Electricity, pp. 8, 14, 32
2. White, Modern College Physics, pp. 396-7, 401
3. Sears & Zemansky, University Physics, pp. 569, 615, 621
4. Timbie, Basic Electricity for Communications, pp. 9-12, pp. 143
5. Halliday & Resnick, Physics, pp. 616, 761

GATHERING THE DATA:

1. Wire circuit.



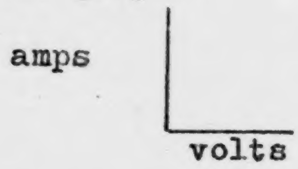
carefully select wire length so that when microgator clip is connected to it, - -when voltmeter 5v then ammeter 5a.

2. a) After proper wire length has been selected, raise voltage from 0 to 5 volts in 0.5v. steps and record data in table:

Wire	E (Volts)	I (amps)
A	0	
A	0.5	
A	5	5

DO NOT EXCEED 5 AMPS.

b) Plot graph:



3. Repeat step #2 for wire 2x length of wire A.
   a) start with 0.5v, & record corresponding amperes.
   b) increase voltage in 0.5v steps to 5v &

Wire	E (Volts)	I (amps)
2A	0.5	

PROBLEM: To experimentally examine the relationship between voltage and current.

APPARATUS:

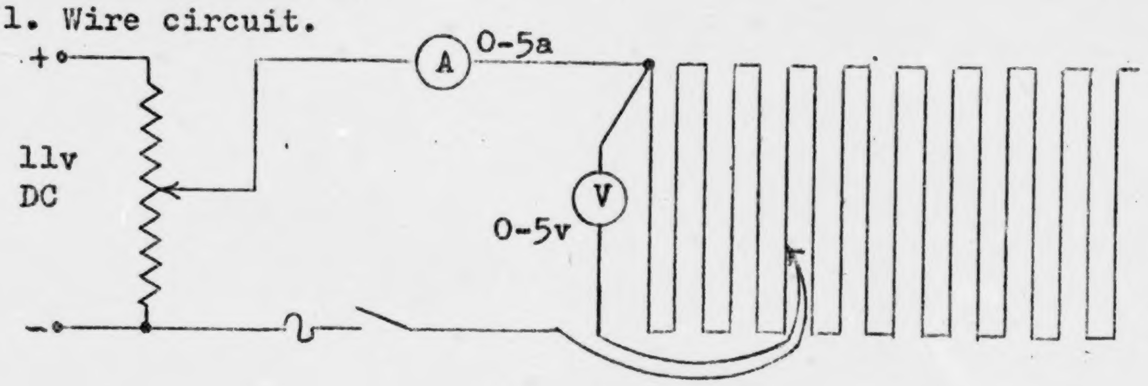
0-5a ammeter
0-15v Weston voltmeter
Fuse and fuse holder
Peg board and wire
SPST switch
10 clip leads
2 microgator clip leads
Potentiometer

REFERENCES:

1. Turner, Basic Electricity, pp. 8, 14, 32
2. White, Modern College Physics, pp. 396-7, 401
3. Sears & Zemansky, University Physics, pp. 569, 615, 621
4. Timbie, Basic Electricity for Communications, pp. 9-12 pp. 143
5. Halliday & Resnick, Physics, pp. 616, 761

GATHERING THE DATA:

1. Wire circuit.



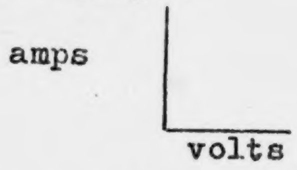
carefully select wire length so that when microgator clip is connected to it, -when voltmeter 5v then ammeter 5a.

2. a) After proper wire length has been selected, raise voltage from 0 to 5 volts in 0.5v. steps and record data in table:

Wire	E (Volts)	I (amps)
A	0	
A	0.5	
A	5	5

DO NOT EXCEED 5 AMPS.

b) Plot graph:



3. Repeat step #2 for wire 2x length of wire A.
   a) start with 0.5v, & record corresponding amperes.
   b) increase voltage in 0.5v steps to 5v & record corresponding amperes in table.
4. Repeat step #3 for wire 4x length of wire A.

Wire	E (Volts)	I (amps)
2A	0.5	
2A	5	
4A	0.5	
4A	5	

SUMMATION:

1. According to experimental data, what is the relation between voltage and current?
2. Express this relation between voltage and current in equation form.
3. What is the constant of proportionality called?
4. What is the name commonly associated with this equation?
5. Define the electrical unit called ohm according to experimental data.
6. Describe other arbitrary ways of defining the volt, the ampere, & the ohm. Write 3 forms of the law developed in this experiment.

Station

Exp. #
56

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

Team

> "The trials and practical difficulties of the laboratory are too valuable educationally to be set aside by over-help."
>
> A. G. Earl

> "Everything is more complicated than it at first seems to most people."
>
> Frederick L. Allen

PROBLEM: To measure resistance by the voltmeter-ammeter method.

APPARATUS:

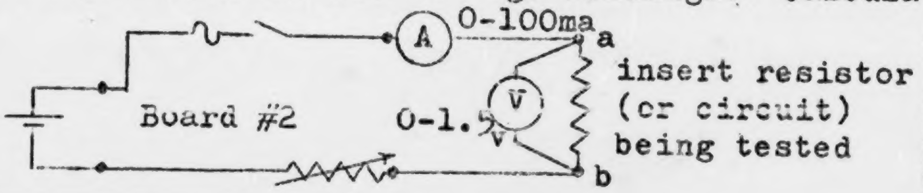
- Resistance board #2
- 0-100ma meter
- 0-1.5-15 voltmeter
- 2 1½v. batteries
- 1/8a fuse & holder
- 1500 ohm resistor
- 15 clip leads
- 5K rheostat
- Peg board
- 9v. battery

REFERENCES:

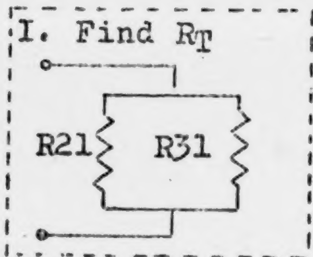
1. USN, Aviation Elec. Mates Manual, pp.5-1 thru 6-3
2. Gerrish, Electricity & Electronics, pp. 36-38, 162-3
3. Philco, Basic Concepts Vol. I, pp. 54-6

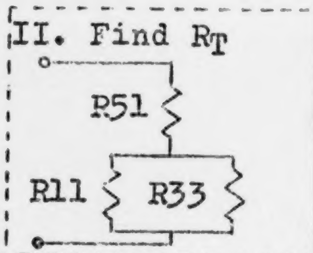
GATHERING THE DATA:

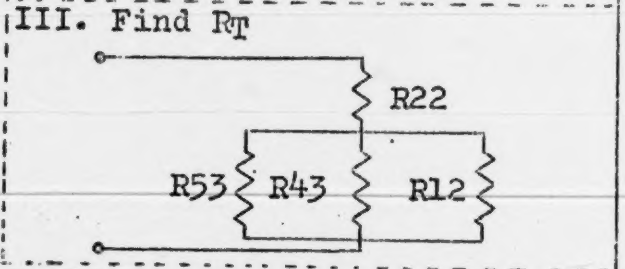
1. Hook up the circuit making certain that:
   a) milliammeter is in series with resistance being checked.
   b) voltmeter is in parallel with resistance being checked.
2. Insert resistance to be checked in circuit.
3. Keep switch open and rheostat set for minimum current before beginning each test. Start each test with just one battery; add an additional battery in series when current readings are too small.
4. Carefully adjust rheostat for an easily read circuit current, preferably large, but not exceeding 100ma. (Do not exceed 1.5 volts)
5. Record current and voltage readings. Calculate R using Ohm's Law.



insert resistor (or circuit) being tested

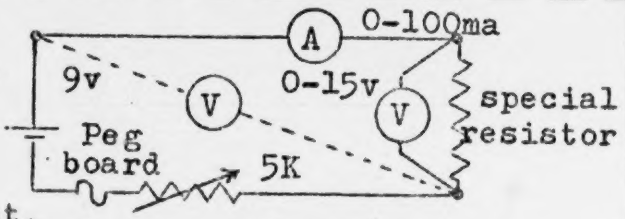

I. Find R_T


II. Find R_T


III. Find R_T

Resistance	E volts	I amps	R = E/I ohms
R11			
R12			
Ckt. I			
Ckt. II			
Ckt. III			

6. Wire circuit shown--5K rheostat must be set for minimum current before connecting battery.
7. Carefully adjust rheostat for approx. 10ma--record volts and amps and calculate R.
8. Open battery, set rheostat for minimum current, relocate volt meter as per dotted line, insert battery, adjust rheostat for the same voltage as in step #7 if necessary, record voltage & amperage, and calculate R.



> Everything is more complicated than it at first seems to most people."
>
> Frederick L. Allen

PROBLEM: To measure resistance by the voltmeter-ammeter method.

APPARATUS:

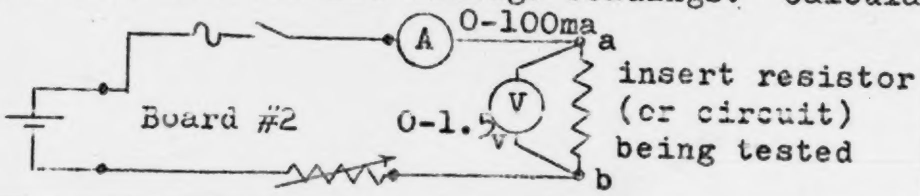
- Resistance board #2
- 0-100ma meter
- 0-1.5-15 voltmeter
- 2 1½v. batteries
- 1/8a fuse & holder
- 1500 ohm resistor
- 15 clip leads
- 5K rheostat
- Peg board
- 9v. battery

REFERENCES:

1. USN, Aviation Elec. Mates Manual, pp.5-1 thru 6-3
2. Gerrish, Electricity & Electronics, pp. 36-38, 162-3
3. Philco, Basic Concepts Vol. I, pp. 54-6

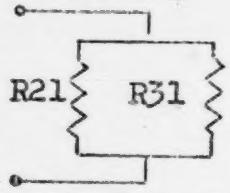
GATHERING THE DATA:

1. Hook up the circuit making certain that:
   a) milliammeter is in series with resistance being checked.
   b) voltmeter is in parallel with resistance being checked.
2. Insert resistance to be checked in circuit.
3. Keep switch open and rheostat set for minimum current before beginning each test. Start each test with just one battery; add an additional battery in series when current readings are too small.
4. Carefully adjust rheostat for an easily read circuit current, preferably large, but not exceeding 100ma. (Do not exceed 1.5 volts)
5. Record current and voltage readings. Calculate R using Ohm's Law.

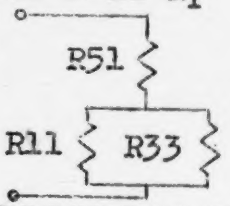


Resistance	E volts	I amps	R = E/I ohms
R11			
R12			
Ckt. I			
Ckt. II			
Ckt. III			

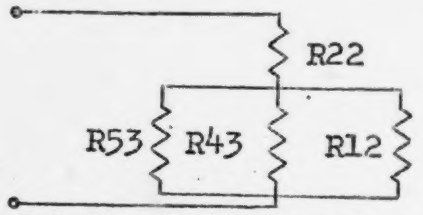
I. Find R_T



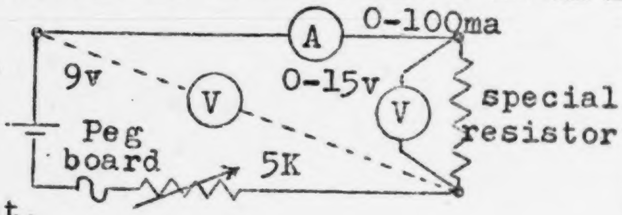
II. Find R_T



III. Find R_T



6. Wire circuit shown--5K rheostat must be set for minimum current before connecting battery.
7. Carefully adjust rheostat for approx. 10ma--record volts and amps and calculate R.
8. Open battery, set rheostat for minimum current, relocate volt meter as per dotted line, insert battery, adjust rheostat for the same voltage as in step #7 if necessary, record voltage & amperage, and calculate R.



SUMMATION:

1. What advantage does the voltmeter-ammeter method have over the ohmmeter method?
2. Calculate the R_T of ckts. I, II, and III by resistance formulas and with results due to the voltmeter-ammeter method.
3. a) Compare the color code resistance of the special resistor wit ments of steps #7 and #8.
   b) Examine the face of the voltmeter. What is the voltmeter's Explain.
   c) What kind of circuit does the voltmeter make with the sp in steps #6 and #7?
   d) What is their combined resistance?
   e) Account for the current & resistance differences in s Explain.

Station

AVIATION HIGH SCHOOL

Exp.# 57

APPLIED PHYSICS LABORATORY

Team

> "Nearly all the quantitative physical laws express relations between numerical measures...proportional to another or to the power of another."
>
> R. T. Glazebrook

PROBLEM: To experimentally determine the factors in wire resistance and their mathematical relationships.

APPARATUS:

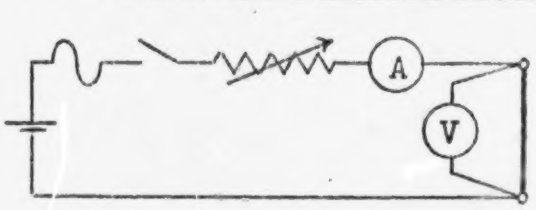
- 1" micrometer
- 0-200ma meter
- 0-1.5v voltmeter
- 2 1½v. batteries
- Graph paper
- ¼a. fuse & holder
- 2 peg boards & wire specimens
- Meter stick
- SPST switch
- Rheostat
- 15 clip leads

REFERENCES:

1. White, Modern College Physics, pp. 401-2
2. Dull, Modern Physics, pp. 434-5
3. Lehrman, Foundations of Physics, p. 378
4. CRC, Handbook of Chemistry & Physics

GATHERING THE DATA:

1. a) Wire circuit.
   b) Switch open & rheostat set for min. current before starting each test.
   c) Insert long nichrome wire in circuit, close switch, adjust rheostat for max. current. (but do not exceed 200ma), record voltage, current, and wire length in table:



(wire being tested)

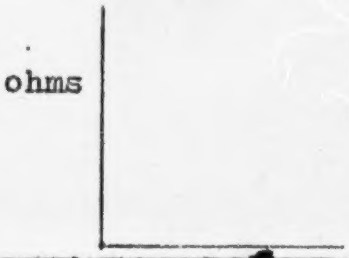
Section	Length m	E volts	I amps	R = E/I ohms
am				
ac				
ab				

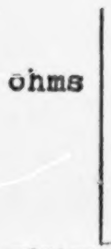
2. a) Insert wire #1 in the circuit and adjust for maximum current, but do not exceed 200ma.
   b) Record voltage, current, and wire length and diameter in table.
   c) Calculate resistances and d^2.
   d) Repeat for wires 2, 3, 4, 5, 6, 7, 8, 9, and 10.

Wire #	Material	Length m	Dia. mils	$(\text{Dia.})^2$ c.m.	E volts	I amps	R = E/I ohms
1							
2							
10							

SUMMATION:

1. Make full page graphs:





PROBLEM: To experimentally determine the factors in wire resistance and their mathematical relationships.

APPARATUS:

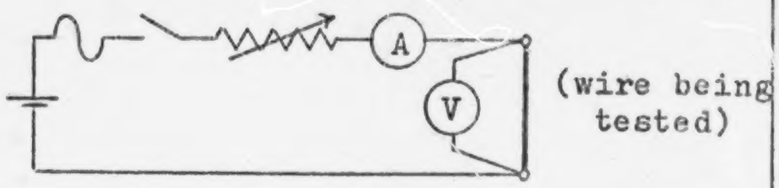
1" micrometer
0-200ma meter
0-1.5v voltmeter
2 1½v. batteries
Graph paper
¼a. fuse & holder
2 peg boards & wire specimens
Meter stick
SPST switch
Rheostat
15 clip leads

REFERENCES:

1. White, Modern College Physics, pp. 401-2
2. Dull, Modern Physics, pp. 434-5
3. Lehrman, Foundations of Physics, p. 378
4. CRC, Handbook of Chemistry & Physics

GATHERING THE DATA:

1. a) Wire circuit.
   b) Switch open & rheostat set for min. current before starting each test.
   c) Insert long nichrome wire in circuit, close switch, adjust rheostat for max. current. (but do not exceed 200ma), record voltage, current, and wire length in table:



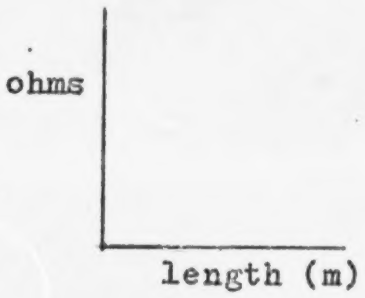
Section	Length m	E volts	I amps	R = E/I ohms
am				
ac				
ab				

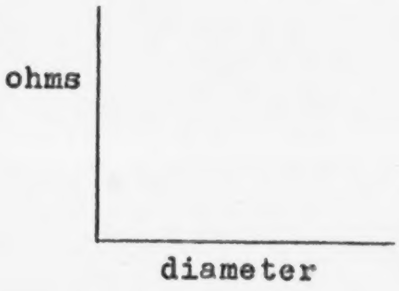
2. a) Insert wire #1 in the circuit and adjust for maximum current, but do not exceed 200ma.
   b) Record voltage, current, and wire length and diameter in table.
   c) Calculate resistances and d^2.
   d) Repeat for wires 2, 3, 4, 5, 6, 7, 8, 9, and 10.

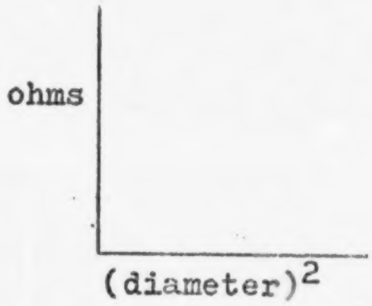
Wire #	Material	Length m	Dia. mils	$(Dia.)^2$ c.m.	E volts	I amps	R = E/I ohms
1							
2							
10							

SUMMATION:

1. Make full page graphs:







2. How does resistance vary with wire length? Explain.
3. Is wire resistance proportional to diameter? Explain.
4. Is wire resistance proportional to $(diameter)^2$? Explain.
5. Wires #8, 9, & 10 have equal lengths & equal diameters, but differ in resistance. Why?
6. The long copper wire on the peg board has the same diameter as wires #8..10.
   a) Insert entire long wire in the circuit and measure its resistance.
   b) How much resistance would it have if it had the same length as #8..10?
   c) Why wasn't a short copper wire with the same length as wires #8, 9, and 10 used?
7. Identify #8, 9, & 10 materials via resistances compared with that of copper.

Station

Exp.# 58

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Search for truth is in one way hard and in another way easy, for it is evident that no one can master it fully nor miss it wholly, but each adds a little to our knowledge of nature and from all the facts assembled there arises a certain grandeur."
>
> Aristotle

PROBLEM: To test variable resistances.

APPARATUS:

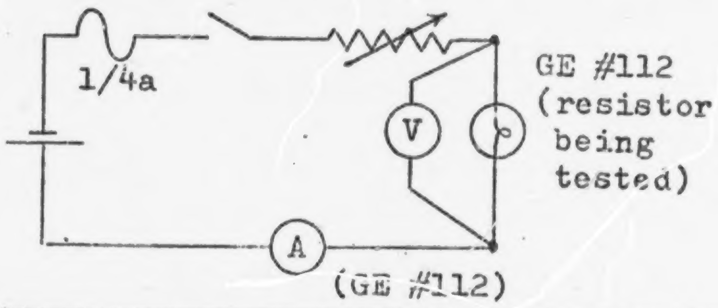
- 0-200ma meter
- 0-1.5v. voltmeter
- 2 1½v. batteries
- GE bulb #112
- Tung Sol bulb #292
- 2 min. lamp bases
- 1/8a. fuse & holder
- 1/4a. fuse & holder
- Graph paper
- Peg board
- SPST switch
- Rheostat
- 20 clip leads

REFERENCES:

1. Philco, Basic Concepts, Vol. I, pp. 43-44 pp. 51-52
2. Dull, Modern Physics, p. 434 pp. 446-7
3. Stollberg, Physics, p. 44

GATHERING THE DATA:

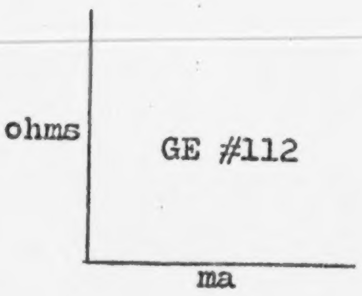
1. a) Wire circuit.
   --switch open and rheostat turned for minimum current before starting each test.
   b) Close switch and adjust rheostat for 8ma.
   --read voltage, calculate resistance & record in table.
   c) Increase current in 8ma steps.
   --read voltages, calculate resistances and record in table.
   --do not exceed 200ma.
2. Repeat step #1 for Tung Sol bulb #292.
   --do not exceed 200ma.
3. Repeat step #1 for 1/8a. fuse
   --do not exceed 120ma.

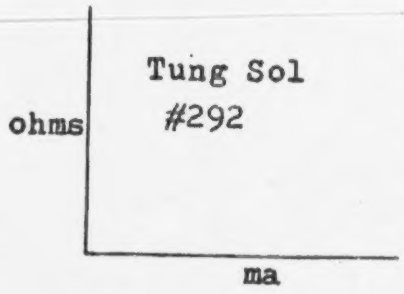


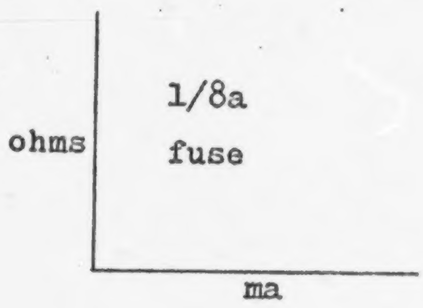
I	E (volts)	R = E/I (ohms)
0.008a		
0.016a		
0.200a		

SUMMATION:

1. Make full page graphs:







2. What is the relation between current and resistance for:
   a) GE #112 lamp?
   b) Tung Sol #292 lamp?

PROBLEM: To test variable resistances.

APPARATUS:

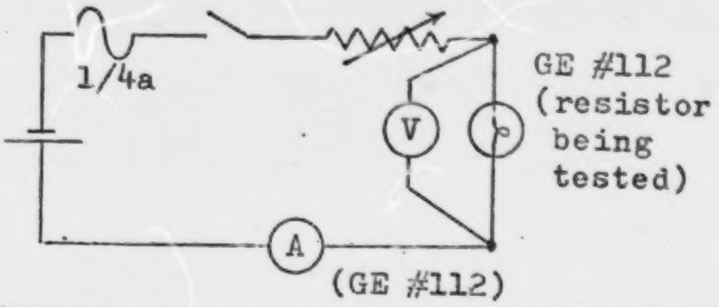
- 0-200ma meter
- 0-1.5v. voltmeter
- 2 1½v. batteries
- GE bulb #112
- Tung Sol bulb #292
- 2 min. lamp bases
- 1/8a. fuse & holder
- 1/4a. fuse & holder
- Graph paper
- Peg board
- SPST switch
- Rheostat
- 20 clip leads

REFERENCES:

1. Philco, Basic Concepts, Vol. I, pp. 43-44; pp. 51-52
2. Dull, Modern Physics, p. 434; pp. 446-7
3. Stollberg, Physics, p. 44

GATHERING THE DATA:

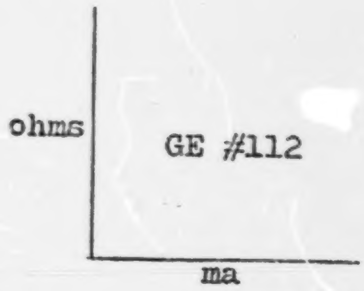
1. a) Wire circuit.
   --switch open and rheostat turned for minimum current before starting each test.
   b) Close switch and adjust rheostat for 8ma.
   --read voltage, calculate resistance & record in table.
   c) Increase current in 8ma steps.
   --read voltages, calculate resistances and record in table.
   --do not exceed 200ma.
2. Repeat step #1 for Tung Sol bulb #292.
   --do not exceed 200ma.
3. Repeat step #1 for 1/8a. fuse
   --do not exceed 120ma.

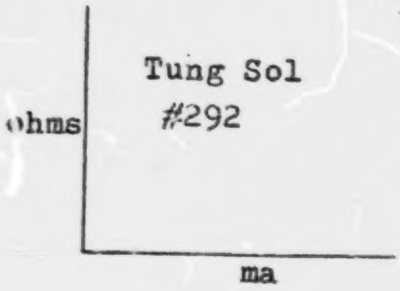


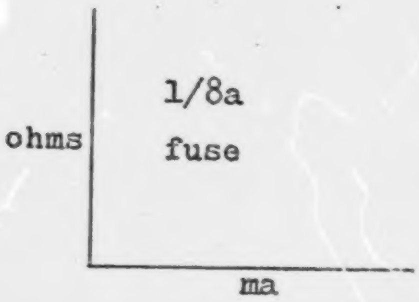
I	E (volts)	R = E/I (ohms)
0.008a		
0.016a		
0.200a		

SUMMATION:

1. Make full page graphs:







2. What is the relation between current and resistance for:
   a) GE #112 lamp?
   b) Tung Sol #292 lamp?
3. What happens to bulb brightness and resistance as current increases?
4. a) Without using electricity, how could the same bulb filament be made to give off light?
   b) In general, what must happen to a wire if it is to give off light?
5. a) How does higher temperature affect a wire's resistance?
   b) Are there any exceptions to #5a?
6. A fuse acts as a current safety by heating up, melting, and breaking the circuit when excessive current passes through it.
   How does fuse wire differ from bulb wire? Explain.
7. Explain step #1 graphs in detail.

Station ⬡ Exp.# 59 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labor in the minute sifting of numerical results."
>
> Lord Kelvin

PROBLEM: To experimentally determine how current distributes in electrical circuits.

APPARATUS:

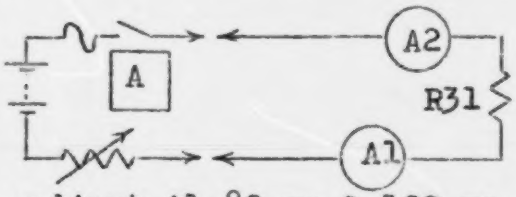
Circuit board #3
5 0-2-- ma meters
4 1½v batteries
30 clip leads

REFERENCES:

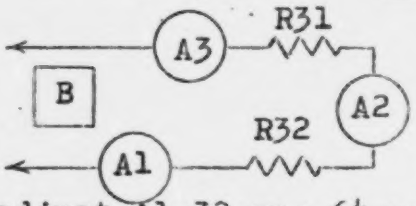
1. Gerrish, Electricity & Electronics, pp. 45-47
2. Philco, Basic Concepts Vol. I, pp. 151-2, 35-37

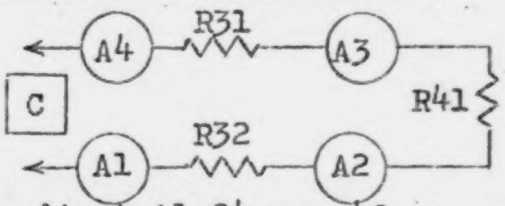
GATHERING THE DATA:

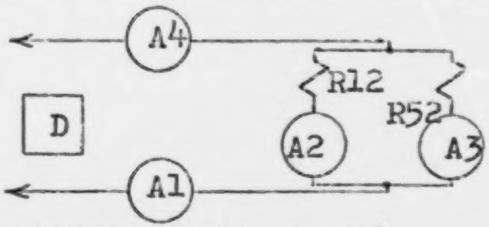
1. a) Wire the following circuits:
   b) Set rheostat for minimum current before switch is closed.
   c) Start each test with just one battery, add more in series if needed.
   d) Adjust for required current and record meter readings on sketches alongside the meter symbols. Use colors to distinguish different sets of readings for the same circuit. Do not exceed req. current.

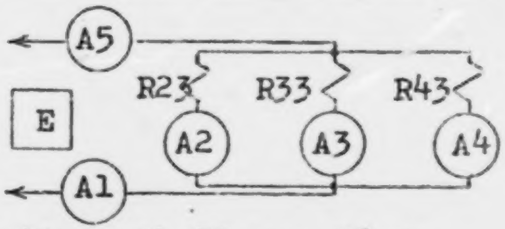


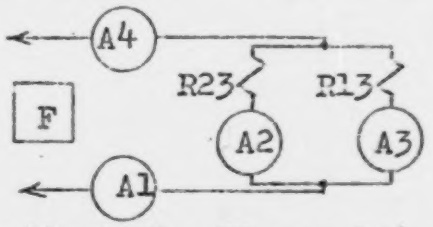
adjust A1=80 ma & 100 ma

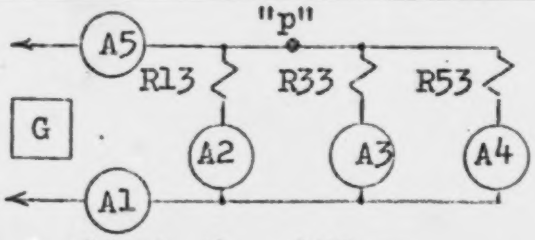

B
A3
R31
A2
R32
A1
adjust A1=32 ma; 64 ma

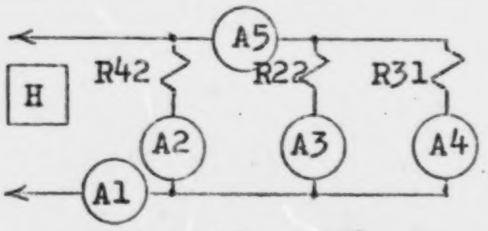

C
A4
R31
A3
R41
R32
A1
A2
adjust A1=24 ma; 40 ma

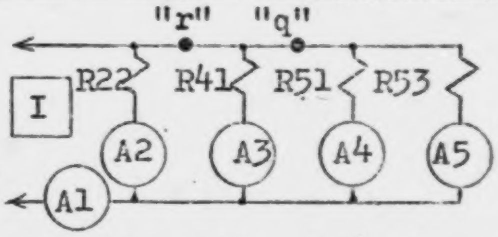

D
A4
R12
R52
A2
A3
A1
adjust A1=32 ma; 96 ma

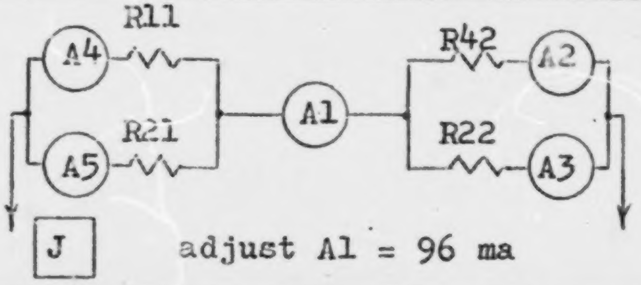

E
A5
R23
R33
R43
A2
A3
A4
A1
adjust A1=72 ma; 96 ma

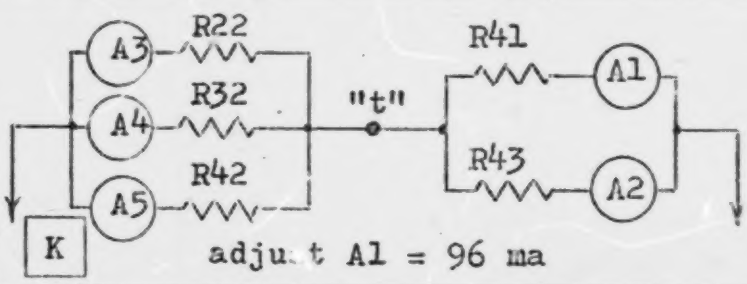

F
A4
R23
R13
A2
A3
A1
adjust A1= 72 ma; 104 ma


G
A5
"p"
R13
R33
R53
A2
A3
A4
A1
adjust A1 = 120 ma


H
A5
R42
R22
R31
A2
A3
A4
A1
adjust A1 = 108 ma


I
"r"
"q"
R22
R41
R51
R53
A2
A3
A4
A5
A1
adjust A1 = 104 ma


J
A4
R11
A5
R21
A1
R42
A2
R22
A3
adjust A1 = 96 ma


K
A3
R22
A4
R32
A5
R42
"t"
R41
A1
R43
A2
adjust A1 = 96 ma

continued labor in the minute sifting of numerical results."

Lord Kelvin

PROBLEM: To experimentally determine how current distributes in electrical circuits.

APPARATUS:

Circuit board #3
5 0-2-- ma meters
4 1½v batteries
30 clip leads

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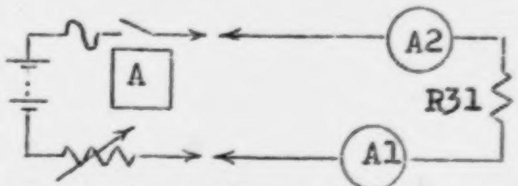
1. Gerrish, Electricity & Electronics, pp. 45-47
2. Philco, Basic Concepts Vol. I, pp. 151-2, 35-37

GATHERING THE DATA:

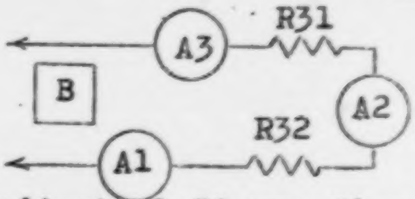
1. a) Wire the following circuits:
   b) Set rheostat for minimum current before switch is closed.
   c) Start each test with just one battery, add more in series if needed.
   d) Adjust for required current and record meter readings on sketches alongside the meter symbols. Use colors to distinguish different sets of readings for the same circuit. Do not exceed req. current.

A



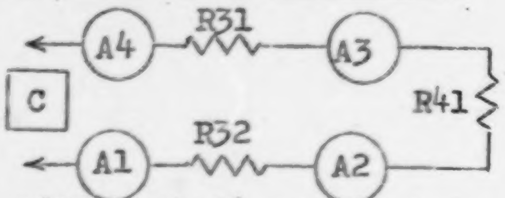
adjust A1=80 ma & 100 ma

B


A3
R31
A2
R32
A1

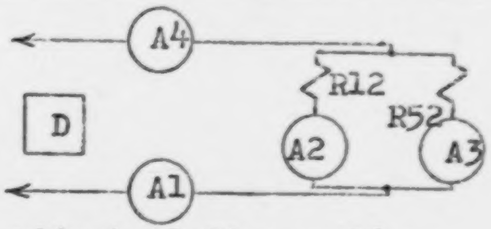
adjust A1=32 ma; 64 ma

C


A4
R31
A3
R41
A1
R32
A2

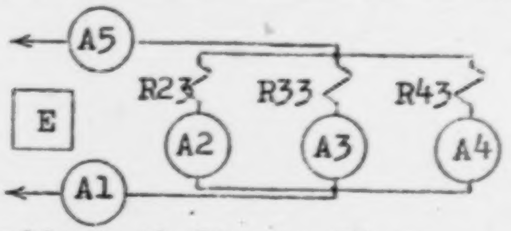
adjust A1=24 ma; 40 ma

D


A4
R12
R52
A2
A3
A1

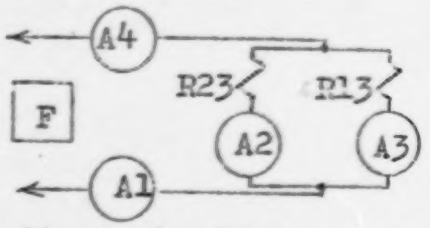
adjust A1=32 ma; 96 ma

E


A5
R23
R33
R43
A2
A3
A4
A1

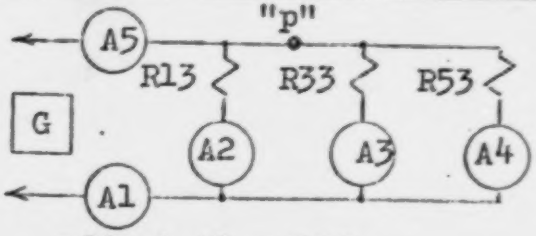
adjust A1=72 ma; 96 ma

F


A4
R23
R13
A2
A3
A1

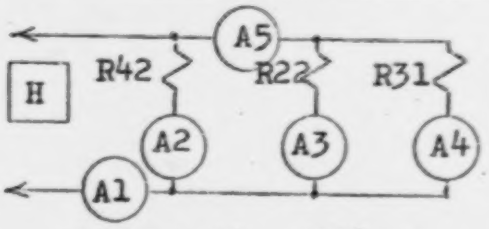
adjust A1= 72 ma; 104 ma

G


A5
"p"
R13
R33
R53
A2
A3
A4
A1

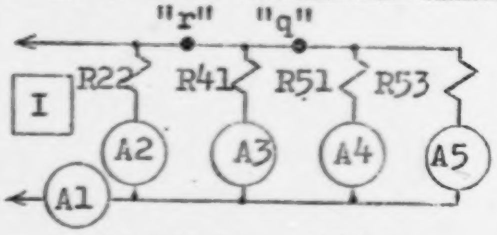
adjust A1 = 120 ma

H


A5
R42
R22
R31
A2
A3
A4
A1

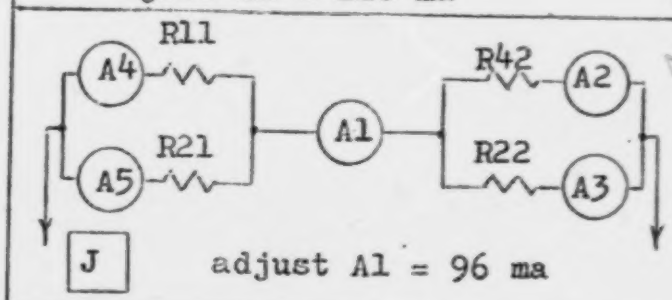
adjust A1 = 108 ma

I


"r"
"q"
R22
R41
R51
R53
A2
A3
A4
A5
A1

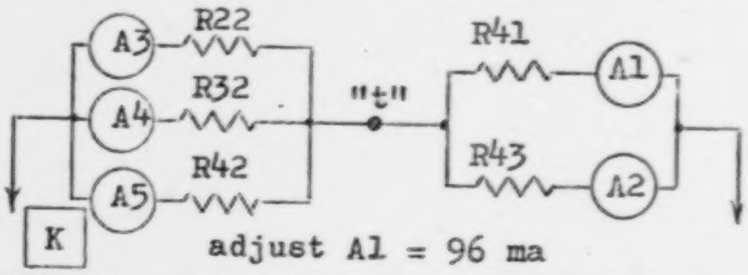
adjust A1 = 104 ma

J


R11
A4
R21
A5
A1
R42
A2
R22
A3

adjust A1 = 96 ma

K


R22
A3
R32
A4
R42
A5
"t"
R41
A1
R43
A2

adjust A1 = 96 ma

SUMMATION:

1. At points where two or more wires meet, what is the relation between the current entering the junction and that leaving according to the data gathered?
2. What law expresses this relationship? Express the law mathematically.
3. Which three resistors are equal? Explain!
4. How many times is R11 larger than R21? Explain!
5. How many times is R33 larger than R53? Explain!
6. How many times is R42 larger than R22? Explain!
7. How much current "flows" through points "p", "q", "r", "t"? Justify answers.

Station ⬡ Exp. # 60 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

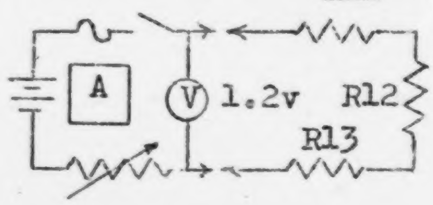
> "I feel more vexed at impropriety in a scientific laboratory, than in a church. The study of nature is intercourse with the Highest Mind."
>
> Louis Agassiz

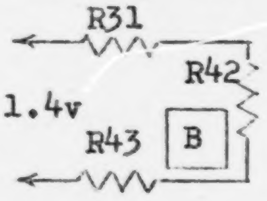
PROBLEM: To determine the distribution of voltage about electrical circuits.

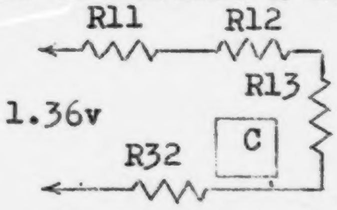
APPARATUS:	REFERENCES:
0-1.5v. voltmeter DC Circuit board #4 30 clip leads 2 - 1½v. batteries	1. Philco, Basic Concepts Vol. I, pp. 148-51 2. White, Modern College Physics, pp. 405-6

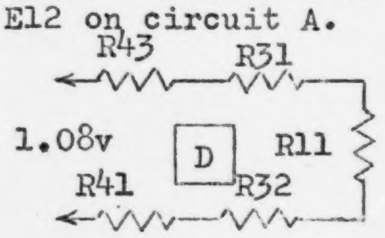
GATHERING THE DATA:

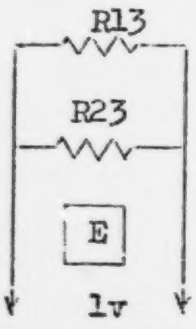
1. Wire the following circuits:
   - set rheostat for minimum voltage before closing switch.
   - adjust for required voltage--do not exceed.
2. Carefully check the voltage across each resistor and record on sketch in report. Record the voltage for R12 of circuit A as E12 on circuit A.

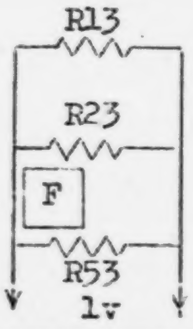

R11
A
V
1.2v
R12
R13

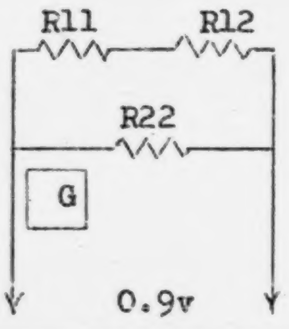

R31
R42
1.4v
R43
B

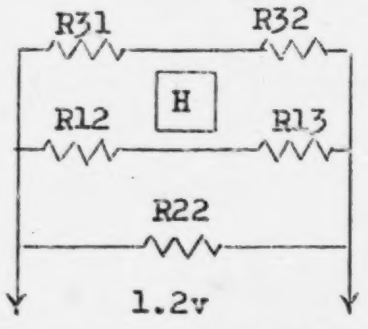

R11
R12
R13
1.36v
R32
C

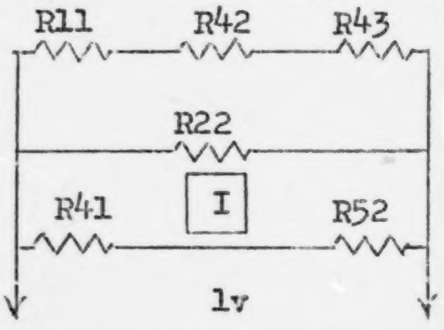

R43
R31
1.08v
D
R11
R41
R32

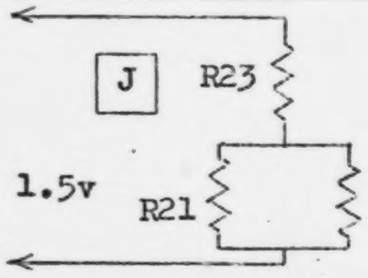


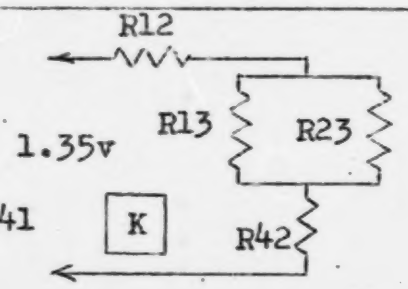

R13
R23
F
R53
1v

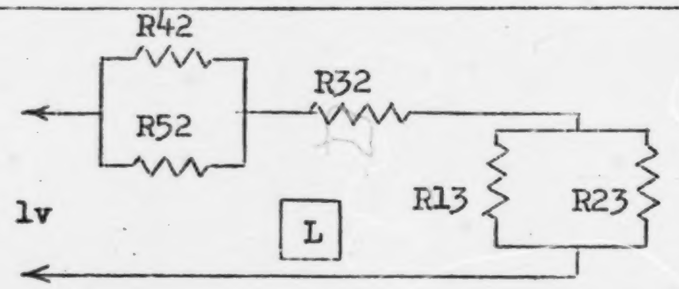

R11
R12
R22
G
0.9v

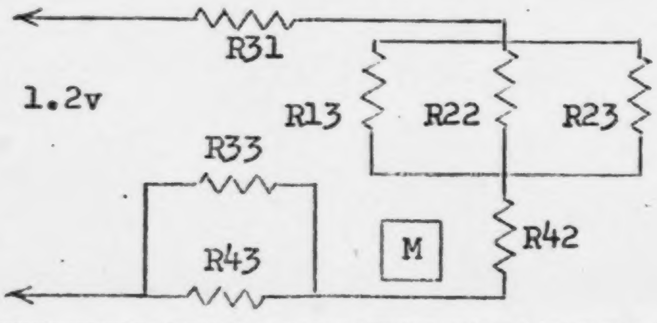

R31
R32
H
R12
R13
R22
1.2v

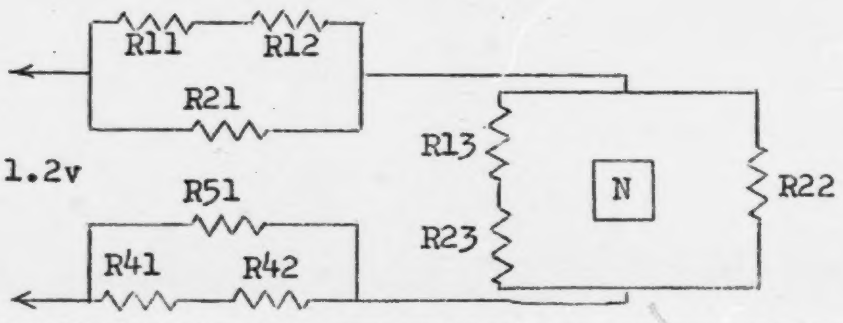

R11
R42
R43
R22
R41
I
R52
1v


J
R23
1.5v
R21
R41


R12
1.35v
R13
R23
K
R42


R42
R32
R52
1v
R13
R23
L


R31
1.2v
R13
R22
R23
R33
R43
M
R42


R11
R12
R21
1.2v
R13
N
R22
R51
R23
R41
R42

PROBLEM: To determine the distribution of voltage about electrical circuits.

APPARATUS:

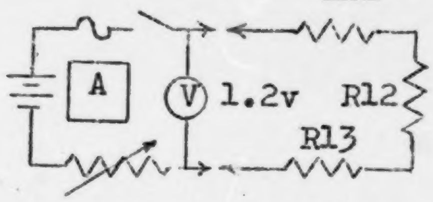
0-1.5v. voltmeter DC
Circuit board #4
30 clip leads
2 - 1½v. batteries

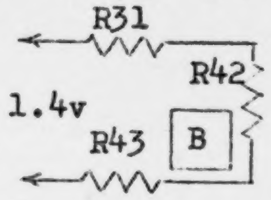
REFERENCES:

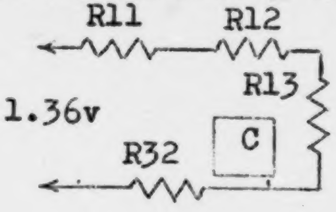
1. Philco, Basic Concepts Vol. I, pp. 148-51
2. White, Modern College Physics, pp. 405-6

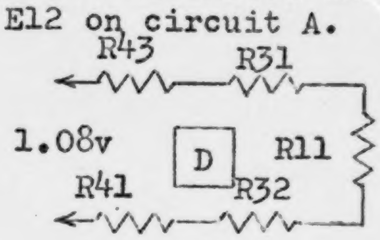
GATHERING THE DATA:

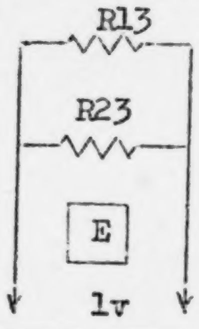
1. Wire the following circuits:
   - set rheostat for minimum voltage before closing switch.
   - adjust for required voltage--do not exceed.
2. Carefully check the voltage across each resistor and record on sketch in report. Record the voltage for R12 of circuit A as E12 on circuit A.

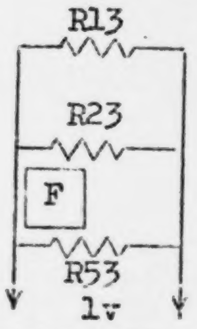

R11
A
V
1.2v
R12
R13

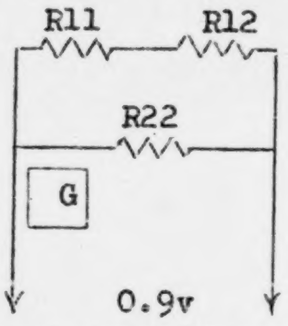

R31
1.4v
R42
R43
B

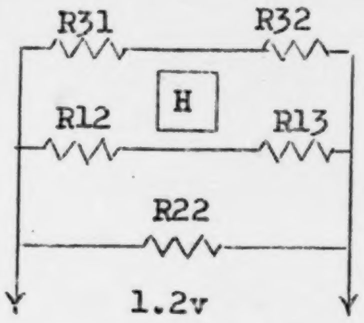

R11
R12
1.36v
R13
R32
C

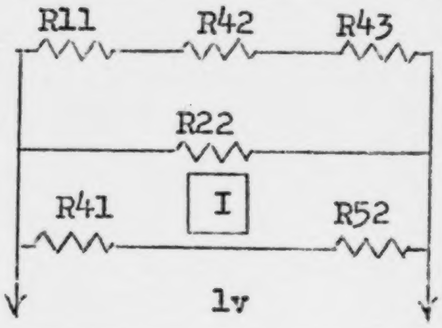

R43
R31
1.08v
D
R11
R41
R32

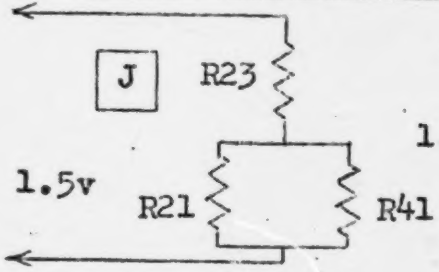


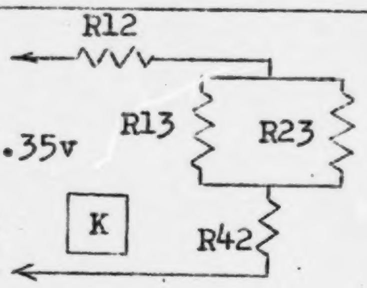

R13
R23
F
R53
1v

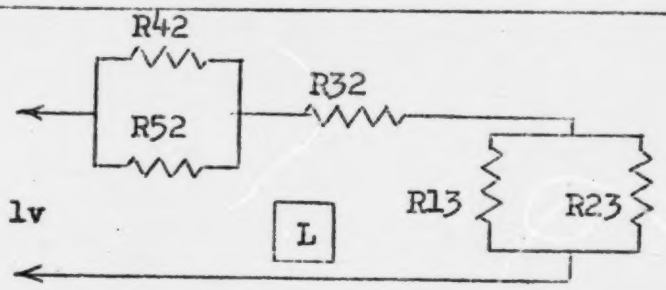

R11
R12
R22
G
0.9v

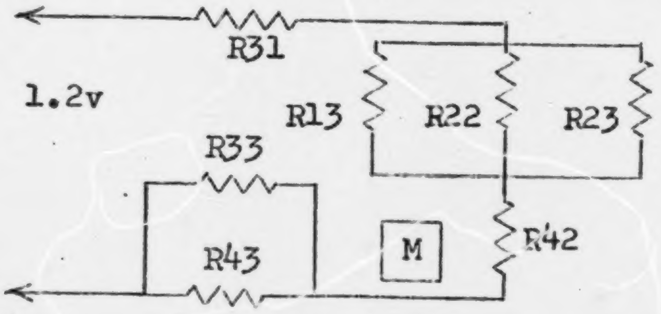

R31
R32
H
R12
R13
R22
1.2v

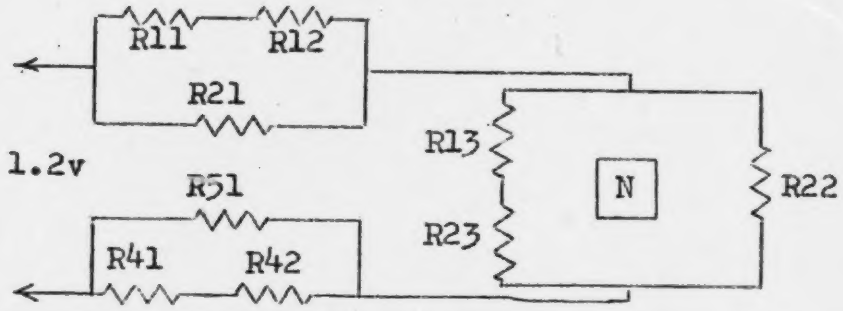

R11
R42
R43
R22
R41
I
R52
1v


J
R23
1.5v
R21
R41


R12
1.35v
R13
R23
K
R42


R42
R52
R32
1v
R13
R23
L


R31
1.2v
R13
R22
R23
R33
R43
M
R42


R11
R12
R21
1.2v
R13
R51
N
R22
R23
R41
R42

SUMMATION:

1. What voltage relationship holds for all the series circuits investigated?
2. In the parallel circuits, what voltage relationship holds for the branches?
3. Is Kirchhoff's voltage law verified by the series parallel circuit data? Explain.
4. Devise and implement an experiment which will detect the smallest resistor and the largest resistor on the board, using the equipment provided. Indicate which resistors they are, sketch the circuits used, tabulate required meter readings, and explain how decisions were arrived at.
5. Repeat #4 to determine which row has resistors all of equal size.

Station

Exp.# 61

AVIATION HIGH SCHOOL **APPLIED PHYSICS LABORATORY**

Team

> "Knowledge in all physical sciences...is based on observation. But observation can only ascertain what is. How can we predict what will be? To that end observation must be combined with mathematics."
>
> Hermann Weyl

PROBLEM: To analyze circuits using a voltmeter and electrical laws.

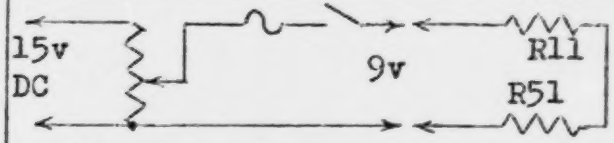
APPARATUS:

- 0-15v. voltmeter
- Circuit board #9
- 20 clip leads
- ¼a fuse & holder
- SPST switch
- table leads
- potentiometer

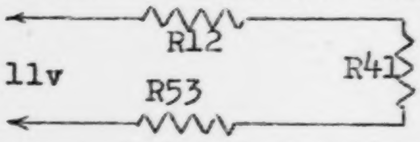
REFERENCES:

GATHERING THE DATA:

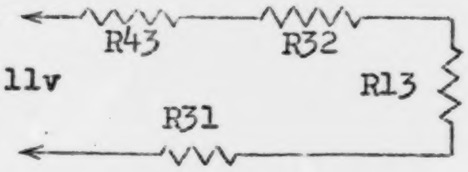
1. Given R11 = 60 ohms, R12 = 30 ohms, R13 = 50 ohms. Find missing data.


15v
DC
9v
R11
R51

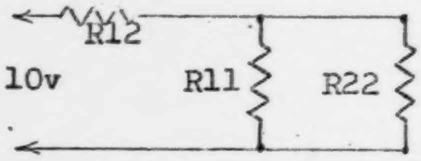
E11__ I51__
I11__ R51__
E51__


R12
11v
R53
R41

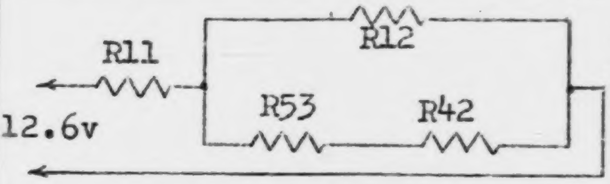
E12 __R41 __
I12 __E53 __
E41 __R53 __


R43
R32
11v
R13
R31

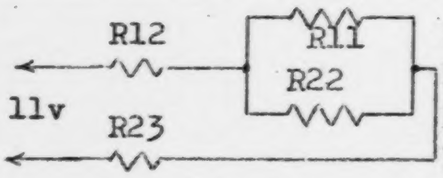
Shorted res. __
E43 __ E31 __ R32 __
E32 __ I13 __ R31 __
E13 __ R43 __


R12
10v
R11
R22

E12 __ R12 __
I12 __ E11 __
I11 __ R22 __


R11
R12
12.6v
R53
R42

E11 __ I12 __
E12 __ I11 __
E53 __ I53 __
E42 __ R42 __

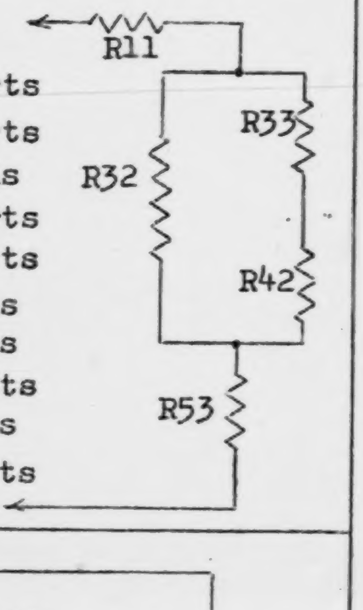

R12
R11
R22
11v
R23

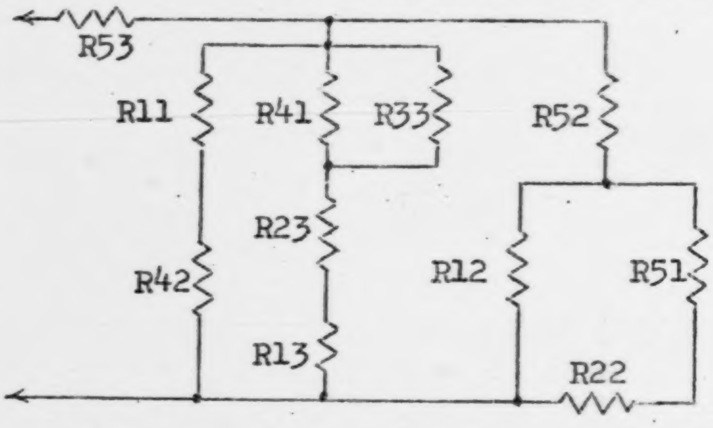
E12 __ I22 __
E11 __ I23 __
E22 __ R22 __
E23 __ R23 __

2. In the following circuits:
   a) mentally insert the prescribed difficulty and give theoretical answer as (d) decreases (o) zero value Use constant 11v. supply.
   (i) increases (u) unchanged
   b) actually insert difficulty in circuit and check theoretical answer by experiment.

T Ex

__ __ E32 if R11 shorts
__ __ I11 if R53 shorts
__ __ I33 if R32 opens
__ __ E42 if R33 shorts
__ __ E11 if R42 shorts
__ __ E33 if R42 opens
__ __ I53 if R32 opens
__ __ E33 if R53 shorts
__ __ E32 if R33 opens
__ __ I33 if R42 shorts


R11
R33
R32
R42
R53


R53
R11
R41
R33
R52
R23
R42
R12
R51
R13
R22

T Ex

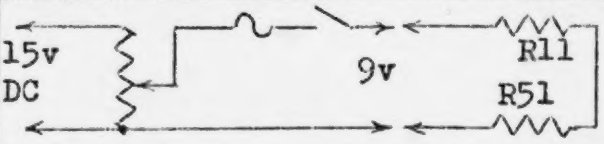
__ __ E53 if R42 shorts
__ __ E33 if R41 opens
__ __ E53 if R52 shorts
__ __ I51 if R22 shorts

PROBLEM: To analyze circuits using a voltmeter and electrical laws.

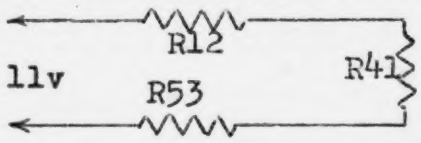
APPARATUS:		REFERENCES:
0-15v. voltmeter	SPST switch	
Circuit board #9	table leads	
20 clip leads	potentiometer	
¼a fuse & holder		

GATHERING THE DATA:

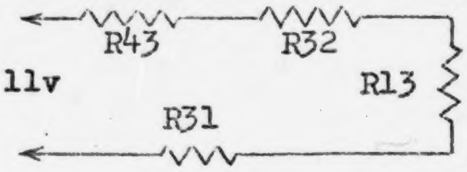
1. Given R11 = 60 ohms, R12 = 30 ohms, R13 = 50 ohms. Find missing data.


15v
DC
9v
R11
R51

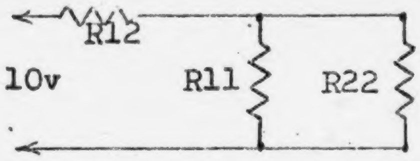
E11__ I51__
I11__ R51__
E51__


R12
11v
R53
R41

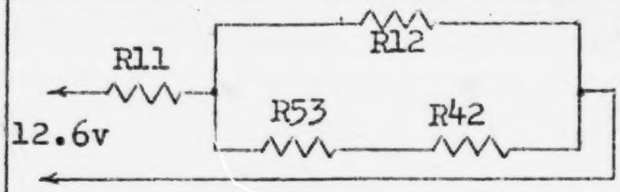
E12 __ R41 __
I12 __ E53 __
E41 __ R53 __


R43
R32
11v
R13
R31

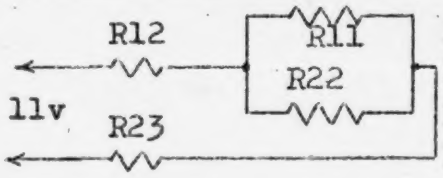
Shorted res. __
E43 __ E31 __ R32 __
E32 __ I13 __ R31 __
E13 __ R43 __


R12
10v
R11
R22

E12 __ R12 __
I12 __ E11 __
I11 __ R22 __

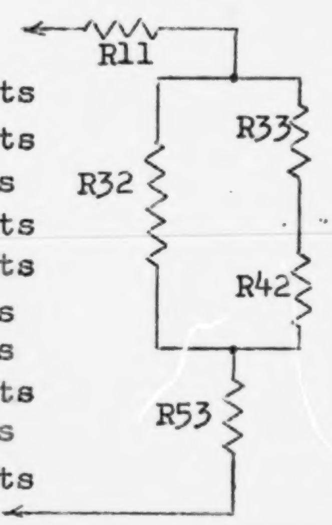

R11
R12
12.6v
R53
R42

E11 __ I12 __
E12 __ I11 __
E53 __ I53 __
E42 __ R42 __

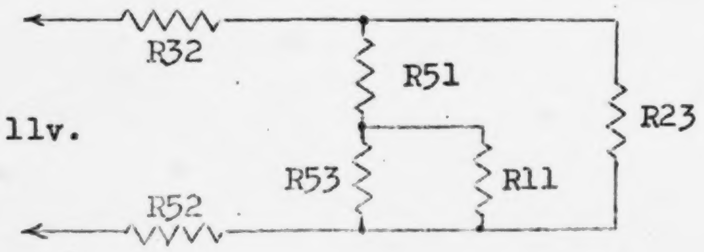

R12
R11
R22
11v
R23

E12 __ I22 __
E11 __ I23 __
E22 __ R22 __
E23 __ R23 __

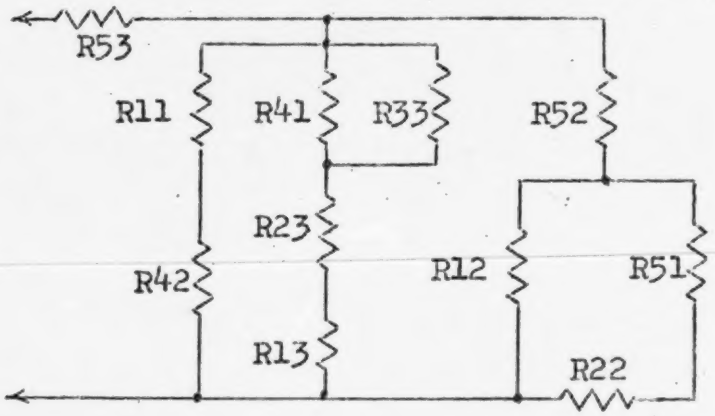
2. In the following circuits:
   a) mentally insert the prescribed difficulty and give theoretical answer as (d) decreases (o) zero value **Use constant 11v. supply.**
   (i) increases (u) unchanged
   b) actually insert difficulty in circuit and check theoretical answer by experiment.


R11
R33
R32
R42
R53

T	Ex	
__	__	E32 if R11 shorts
__	__	I11 if R53 shorts
__	__	I33 if R32 opens
__	__	E42 if R33 shorts
__	__	E11 if R42 shorts
__	__	E33 if R42 opens
__	__	I53 if R32 opens
__	__	E33 if R53 shorts
__	__	E32 if R33 opens
__	__	I33 if R42 shorts


R32
R51
R23
11v.
R53
R11
R52

T	Ex	
__	__	E23 if R32 shorts
__	__	I53 if R51 shorts
__	__	E52 if R51 opens
__	__	E11 if R53 shorts
__	__	E53 if R11 opens
__	__	I23 if R51 shorts
__	__	E11 if R52 shorts
__	__	I32 if R11 opens


R53
R11
R41
R33
R52
R23
R42
R12
R51
R13
R22

T	Ex	
__	__	E53 if R42 shorts
__	__	E33 if R41 opens
__	__	E53 if R52 shorts
__	__	I51 if R22 shorts
__	__	E51 if R12 shorts
__	__	I53 if R12 shorts
__	__	E52 if R12 opens
__	__	E11 if R23 opens
__	__	I42 if R11 shorts
__	__	E41 if R33 opens
__	__	E53 if R23 opens
__	__	E42 if R12 shorts
__	__	E52 if R11 opens
__	__	I33 if R11 shorts
__	__	E12 if R52 shorts
__	__	I13 if R23 shorts
__	__	I51 if R42 shorts
__	__	E13 if R52 opens

Station

Exp. # 62

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

Team

"... one must learn by doing the thing; for though you think you know it you have no certainty until you try."

Sophocles

PROBLEM: To diagnose circuit difficulties via symptoms.

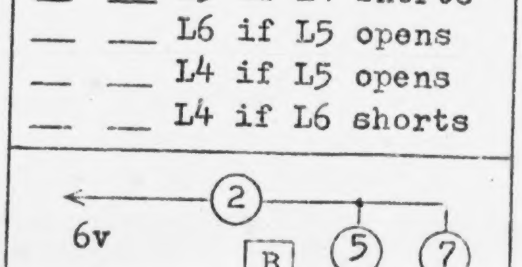
APPARATUS:

- 0-15v voltmeter
- 10 GE 40 bulbs
- 2 GE 41 bulbs
- 1½ v battery
- 30 clip leads
- SPST switch
- power potentiometer
- 0.5 amp fuse & holder
- 12 min lamp sockets
- peg board
- DC table leads

THEORY: An incandescent lamp glows more brightly when its filament is at a higher temperature. Higher filament temperature requires more current which in turn requires higher voltage across the lamp. Thus if voltage across a lamp increases, the lamp becomes brighter (providing it does not burn out due to excessive current). The bulb becomes dimmer if the voltage across it decreases. Voltage variation is determined by observing resistance rules and applying Kirchhoff's voltage law.

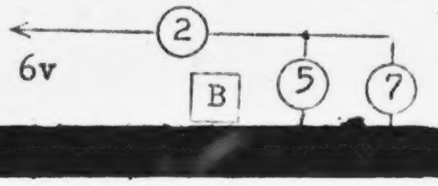
PROCEDURE:

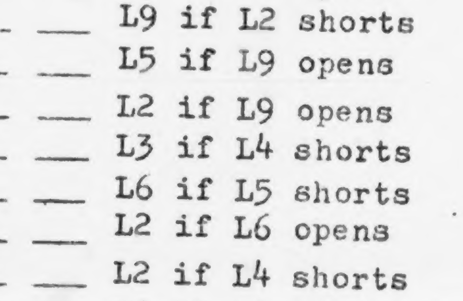
1. Trouble-shoot circuit A & enter theoretical answer under T:
   (b) brighter (o) completely out
   (d) dimmer (u) unchanged
2. Teacher checks T answers before experimentation.
3. Test all bulbs using 1½ v. battery
4. Hook up circuit - switch open & rheostat set for min. E before plugging in.
5. Adjust rheostat for required voltage
   - if bulbs burn too brightly circuit is incorrectly wired.
6. Put given difficulty into circuit, observe symptom & record under Ex.
7. Repeat above steps for other circuits.



T Ex

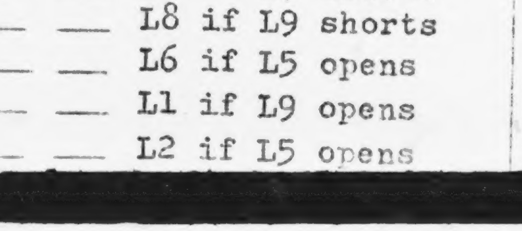
___ ___ L5 if L4 shorts
___ ___ L6 if L5 opens
___ ___ L4 if L5 opens
___ ___ L4 if L6 shorts





T Ex

___ ___ L4 if L6 opens
___ ___ L9 if L2 shorts
___ ___ L5 if L9 opens
___ ___ L2 if L9 opens
___ ___ L3 if L4 shorts
___ ___ L6 if L5 shorts
___ ___ L2 if L6 opens
___ ___ L2 if L4 shorts



T Ex

___ ___ L8 if L1 opens
___ ___ L3 if L2 shorts
___ ___ L4 if L7 shorts
___ ___ L8 if L9 shorts
___ ___ L6 if L5 opens
___ ___ L1 if L9 opens
___ ___ L2 if L5 opens

PROBLEM: To diagnose circuit difficulties via symptoms.

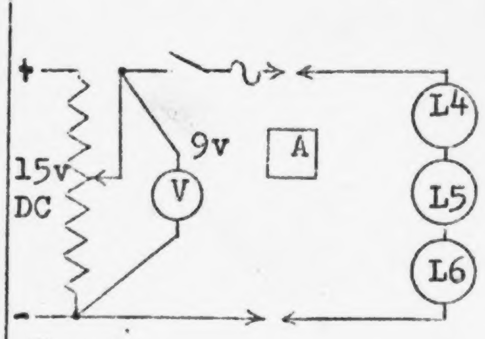
APPARATUS:

0-15v voltmeter	1½ v battery	power potentiometer	peg board
10 GE 40 bulbs	30 clip leads	0.5 amp fuse & holder	DC table leads
2 GE 41 bulbs	SPST switch	12 min lamp sockets	

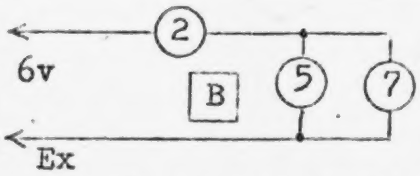
THEORY: An incandescent lamp glows more brightly when its filament is at a higher temperature. Higher filament temperature requires more current which in turn requires higher voltage across the lamp. Thus if voltage across a lamp increases, the lamp becomes brighter (providing it does not burn out due to excessive current). The bulb becomes dimmer if the voltage across it decreases. Voltage variation is determined by observing resistance rules and applying Kirchhoff's voltage law.

PROCEDURE:

1. Trouble-shoot circuit A & enter theoretical answer under T:
   (b) brighter (o) completely out
   (d) dimmer (u) unchanged
2. Teacher checks T answers before experimentation.
3. Test all bulbs using 1½ v. battery
4. Hook up circuit - switch open & rheostat set for min. E before plugging in.
5. Adjust rheostat for required voltage
   - if bulbs burn too brightly circuit is incorrectly wired.
6. Put given difficulty into circuit, observe symptom & record under Ex.
7. Repeat above steps for other circuits.



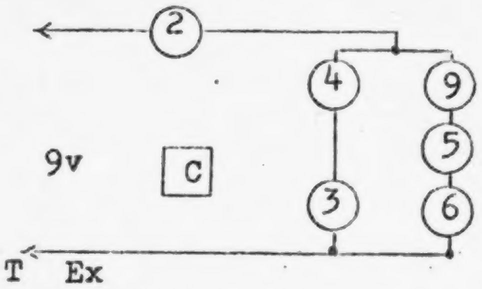
T	Ex	
___	___	L5 if L4 shorts
___	___	L6 if L5 opens
___	___	L4 if L5 opens
___	___	L4 if L6 shorts



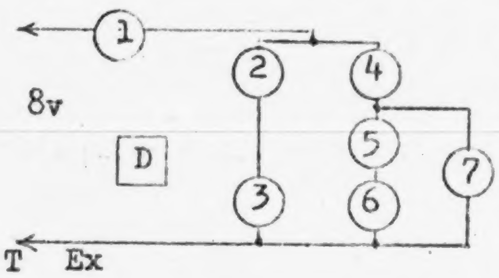
T	Ex	
___	___	L5 if L2 opens
___	___	L2 if L5 shorts
___	___	L5 if L7 shorts
___	___	L2 if L5 opens
___	___	L7 if L5 opens

SUMMATION:

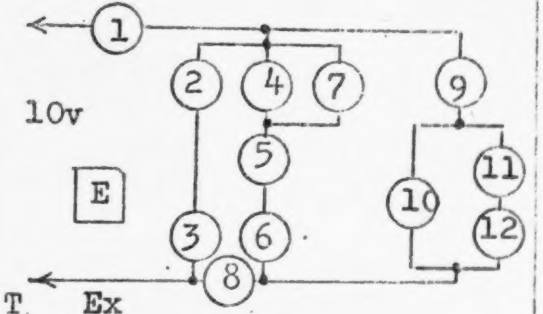
1. Explain all theoretical errors--i.e. T ans. which do not agree with experimental results.
2. If one lamp in a series circuit goes out, do all go out? Explain.



T	Ex	
___	___	L4 if L6 opens
___	___	L9 if L2 shorts
___	___	L5 if L9 opens
___	___	L2 if L9 opens
___	___	L3 if L4 shorts
___	___	L6 if L5 shorts
___	___	L2 if L6 opens
___	___	L2 if L4 shorts
___	___	L6 if L4 shorts



T	Ex	
___	___	L3 if L2 opens
___	___	L5 if L7 shorts
___	___	L6 if L5 opens
___	___	L1 if L4 shorts
___	___	L1 if L3 shorts
___	___	L7 if L5 opens
___	___	L2 if L4 shorts
___	___	L4 if L7 shorts



T	Ex	
___	___	L8 if L1 opens
___	___	L3 if L2 shorts
___	___	L4 if L7 shorts
___	___	L8 if L9 shorts
___	___	L6 if L5 opens
___	___	L1 if L9 opens
___	___	L2 if L5 opens
___	___	L12 if L10 shorts
___	___	L11 if L12 opens
___	___	L7 if L4 shorts
___	___	L1 if L10 shorts
___	___	L7 if L6 opens
___	___	L7 if L8 opens
___	___	L10 if L12 shorts
___	___	L7 if L4 opens
___	___	L2 if L6 opens
___	___	L4 if L9 shorts
___	___	L1 if L9 shorts
___	___	L3 if L5 opens
___	___	L5 if L6 shorts
___	___	L6 if L8 opens
___	___	L8 if L10 opens
___	___	L9 if L10 shorts
___	___	L6 if L9 opens

Station ⬡ AVIATION HIGH SCHOOL Exp.# 63 APPLIED PHYSICS LABORATORY Team ○

> "If you want to know the essence of scientific method don't listen to what a scientist may tell you. Watch what he does."
>
> Albert Einstein

PROBLEM: To construct a slide-wire Wheatstone Bridge and to measure resistances with it.

APPARATUS:

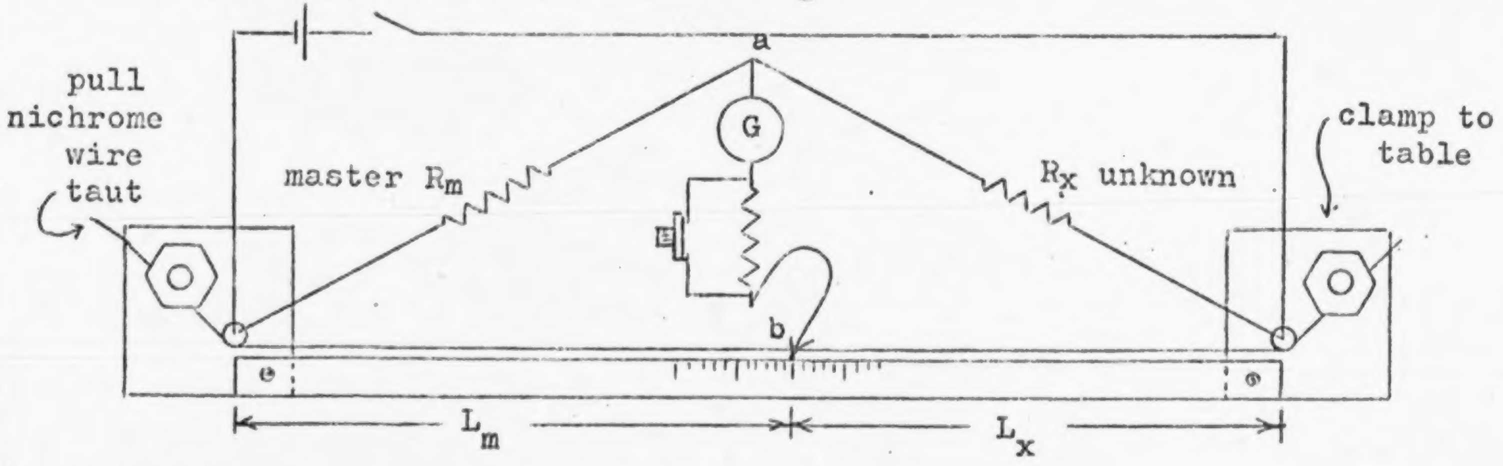
- Circuit board #6
- 0-250 microamp meter
- Micro-gator clip lead
- 1½v battery
- Resistor array F
- Master resistors
- 4' #28 nichrome wire
- Meter stick
- 2 pin blocks
- 2 C clamps
- 15 clip leads
- SPST switch
- Peg board

REFERENCES

1. Philco, Basic Concepts - Vol. I, p 170-2
2. Dull, Modern Physics, pp. 438-40
3. White, Modern College Physics, p. 409

GATHERING THE DATA:

1. Construct slide-wire Wheatstone Bridge.



2. Check R11.
   a) Insert in circuit as shown (use 60 ohm master).
   b) Close switch, tap microgator clip at center of nichrome wire, avoid excessive meter reading, and carefully move contact to point where galvanometer reads zero.
   c) Press red button and adjust for more sensitive null.
   Caution: when red button pressed, each galvanometer division = 0.000010 amperes!
   d) Carefully determine L_m & L_x, record in table & compute R11 = R_x.

Unknown Resistor	R_m ohms	L_x cm	L_m cm	$R_x = \frac{R_m L_x}{L_m}$
R11	60			
R12	60			
R53	60			

Unknown	R_m ohms	L_x cm	L_m cm	$R_x = \frac{R_m L_x}{L_m}$
A	1000			
B	1000			
etc.	1000			

3. Repeat step #2 for each resistor on board #6 & on resistor array F.

SUMMATION:

1. When galvanometer reads zero:

PROBLEM: To construct a slide-wire Wheatstone Bridge and to measure resistances with it.

APPARATUS:

Circuit board #6
0-250 microamp meter
Micro-gator clip lead
1½v battery
Resistor array F
Master resistors
4' #28 nichrome wire
Meter stick
2 pin blocks
2 C clamps
15 clip leads
SPST switch
Peg board

REFERENCES

1. Philco, Basic Concepts - Vol. I, p 170-2
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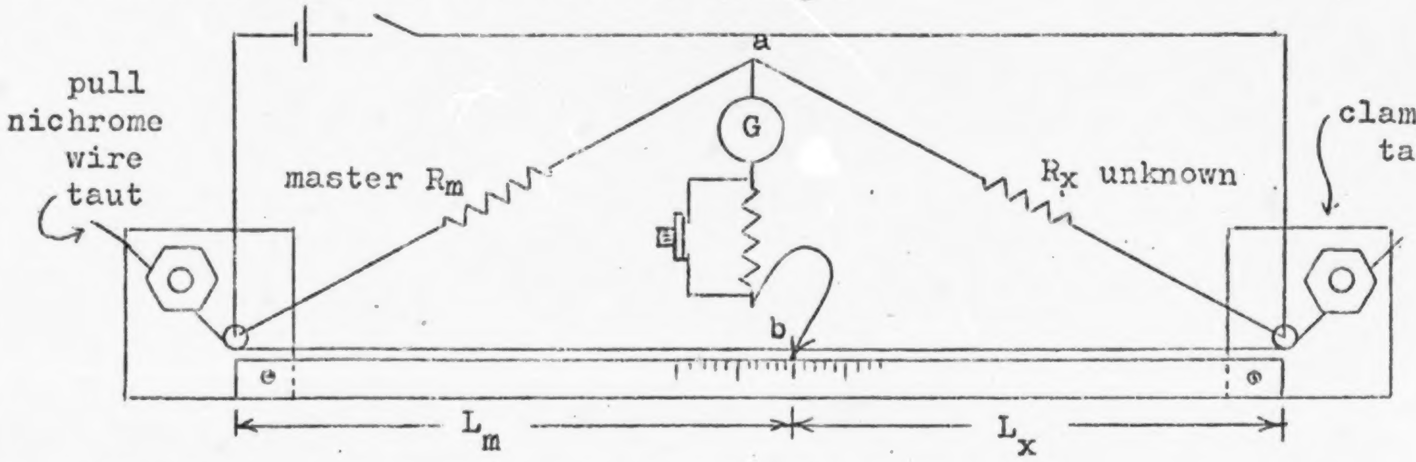
GATHERING THE DATA:

1. Construct slide-wire Wheatstone Bridge.



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   a) Insert in circuit as shown (use 60 ohm master).
   b) Close switch, tap microgator clip at center of nichrome wire, avoid excessive meter reading, and carefully move contact to point where galvanometer reads zero.
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   Caution: when red button pressed, each galvanometer division = 0.000010 amperes!
   d) Carefully determine L_m & L_x, record in table & compute R11 = R_x.

Unknown Resistor	R_m ohms	L_x cm	L_m cm	$R_x = \frac{R_m L_x}{L_m}$
R11	60			
R12	60			
R53	60			

Unknown	R_m ohms	L_x cm	L_m cm	$R_x = \frac{R_m L_x}{L_m}$
A	1000			
B	1000			
etc.	1000			

3. Repeat step #2 for each resistor on board #6 & on resistor array F.

SUMMATION:

1. When galvanometer reads zero:
   a) What is the potential difference between a and b? Why?
   b) Which voltages E (L_m), E(L_x), E(R_m), and E(R_x) are equal? Why?
2. a) Equate equal voltages, divide equals by equals, & substitute appropriate IR values for E's.
   b) Simplify by cancelling equal currents and replacing wire resistance ratio by its corresponding length ratio.
   c) Solve for R_x.
   d) Why can resistance ratio be replaced by wire length ratio?
3. Slide wire Wheatstone bridge is most accurate when $L_m \doteq L_x$. Prove.
4. Check resistors X, Y, & Z using appropriate masters.
5. How does taking an additional set of readings with the battery polarity reversed improve possibilities for accurate measurements? Describe in detail.

Station ⬡ AVIATION HIGH SCHOOL Exp.# 64 APPLIED PHYSICS LABORATORY Team ○

> "In reality, gathering facts without a formulated reason for doing so and a pretty good idea as to what the facts may mean, is a sterile occupation and has not been the method of any important scientific advance. Indeed, facts are elusive and you usually have to know what you are looking for before you can find one."
>
> George Gaylord Simpson

PROBLEM: To measure galvanometer resistance, and to design, construct, and check voltmeter multipliers.

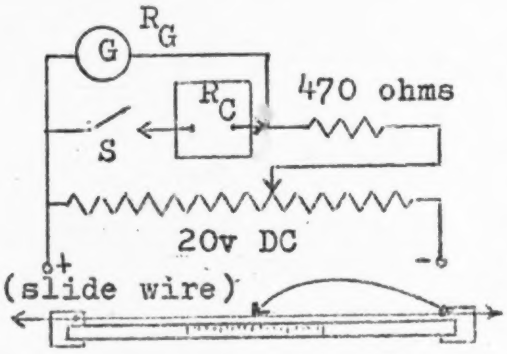
APPARATUS:

Cenco galvanometer
0-15v. voltmeter
Circuit board #7
Power rheostat
Voltage divider
2 SPST switches
Clarostat decade resistance
Peg board
20 clip leads
Table leads
20v. DC
Slide wire

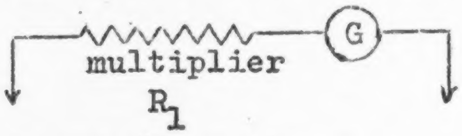
REFERENCES:

1. Sears & Zemansky, University Physics, pp. 654-6
2. Philco, Basic Concepts, Vol. I pp. 37-8 p. 114
3. Dull, Modern Physics, pp. 479-80

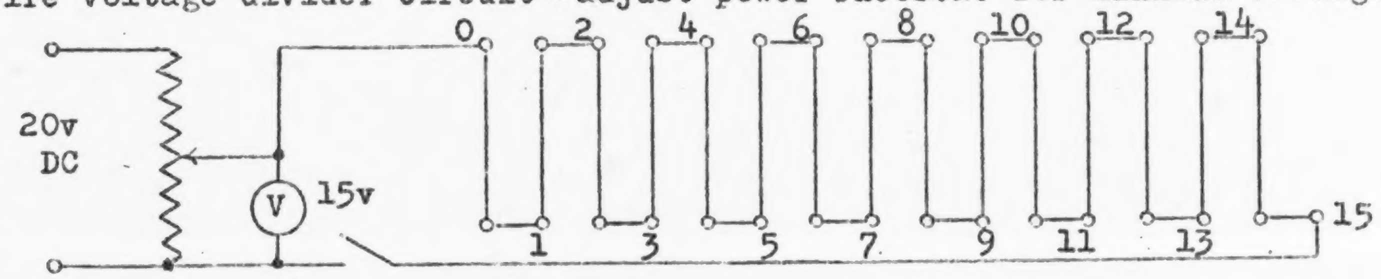
GATHERING THE DATA:



1. Check galvanometer resistance:
   a) wire circuit as shown, switch S open.
   b) adjust potentiometer for full scale galvanometer deflection.
   c) close switch S and adjust clarostat decade resistance (or slide wire) for one-half galvanometer deflection, then: $R_G = R_C$



2. a) Calculate the multiplier resistance required to convert the galvanometer into a 1 volt maximum voltmeter.
   b) Show, with sketch, how the resistors of circuit board #7 can be connected to provide the desired multiplier.
   c) Connect multiplier to the galvanometer.
3. Wire voltage divider circuit--adjust power rheostat for minimum voltage.



4. Show computations and circuit to teacher. Request power.
5. Tap galvanometer--voltmeter leads across 1v. section of voltage divider, gradually adjusting divider voltage to 15v.
   Caution: galvanometer--voltmeter may be damaged if leads touch voltage greater than one volt.
6. Repeat steps #2 through #5 for 5v., 10v., 15v., 50v., and 100v. voltmeters. Have each approved before connecting to electricity.

PROBLEM: To measure galvanometer resistance, and to design, construct, and check voltmeter multipliers.

APPARATUS:

Cenco galvanometer
0-15v. voltmeter
Circuit board #7
Power rheostat
Voltage divider
2 SPST switches
Clarostat decade resistance
Peg board
20 clip leads
Table leads
20v. DC
Slide wire

REFERENCES:

1. Sears & Zemansky, *University Physics*, pp. 654-6
2. Philco, *Basic Concepts, Vol. I* pp. 37-8 p. 114
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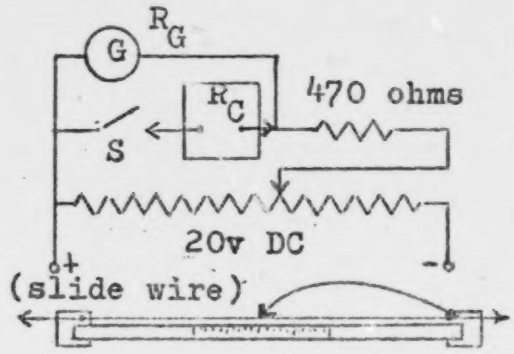
GATHERING THE DATA:



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    b) adjust potentiometer for full scale galvanometer deflection.
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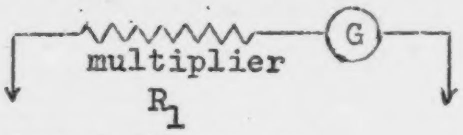
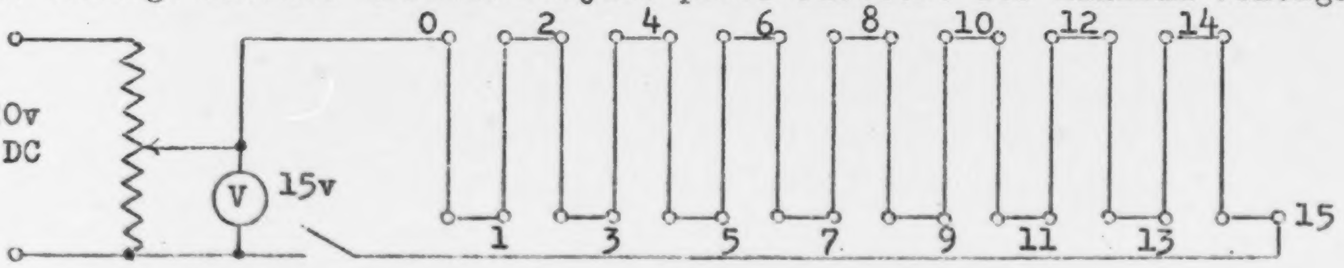


2. a) Calculate the multiplier resistance required to convert the galvanometer into a 1 volt maximum voltmeter.
    b) Show, with sketch, how the resistors of circuit board #7 can be connected to provide the desired multiplier.
    c) Connect multiplier to the galvanometer.
3. Wire voltage divider circuit--adjust power rheostat for minimum voltage.



4. Show computations and circuit to teacher. Request power.
5. Tap galvanometer--voltmeter leads across 1v. section of voltage divider, gradually adjusting divider voltage to 15v.
    Caution: galvanometer--voltmeter may be damaged if leads touch voltage greater than one volt.
6. Repeat steps #2 through #5 for 5v., 10v., 15v., 50v., and 100v.voltmeters. Have each approved before connecting to electricity.

SUMMATION:

1. Explain how the voltage divider:
    a) provides integral voltage steps.
    b) can be converted into a divider with 0.5v. steps to 7.5v. without rewiring.
2. Develop a general equation for determining multiplier size.
3. Using all the resistances of board #7, what is the largest voltage that can be measured?
4. Can the galvanometer be made more sensitive (i.e. capable of responding to smaller voltages) by using a multiplier? Explain.
5. The circuit in step #1 (gathering the data) is a constant current generator --supplying the same total current with or without switch S closed. Explain. Justify $R_G = R_C$.

Station AVIATION HIGH SCHOOL Exp.# 65 APPLIED PHYSICS LABORATORY Team

> "....a vital difference between the approach of the pure scientist and that of the engineer is....found....in the fact that the former starts off on a journey and follows the path that is most pleasing to him.... If on his return he writes a report of his travels, there will be many who find much use in the report. The engineer, however, has his ticket bought for him before he starts. His destination is chosen by others and he is expected to find the road to this destination, sometimes without an ironclad guarantee that the destination exists."
>
> W. F. G. Swann

PROBLEM: To design and construct electrical circuits satisfying prescribed specifications.

APPARATUS:

3 D batteries	1 lampbase
2 rotary switches	1 resistor
6 pushbutton switches	2 pegboards
2 SPDT switches	4 buzzers
1 GE #112 bulb	30 clip leads

REFERENCES:

PROCEDURE:

1. a) Design an electrical circuit satisfying the prescribed specifications for project I.
   -Make a neat freehand electrical schematic.
   b) Trace electron flow and verify:
   --that the battery is not short circuited by the wiring or switch positions.
   --that the circuit does satisfy the prescribed specifications.
   c) Hook up the circuit and verify that it satisfies the given specifications. OBTAIN TEACHER APPROVAL.
2. Repeat step #1 for the other projects.

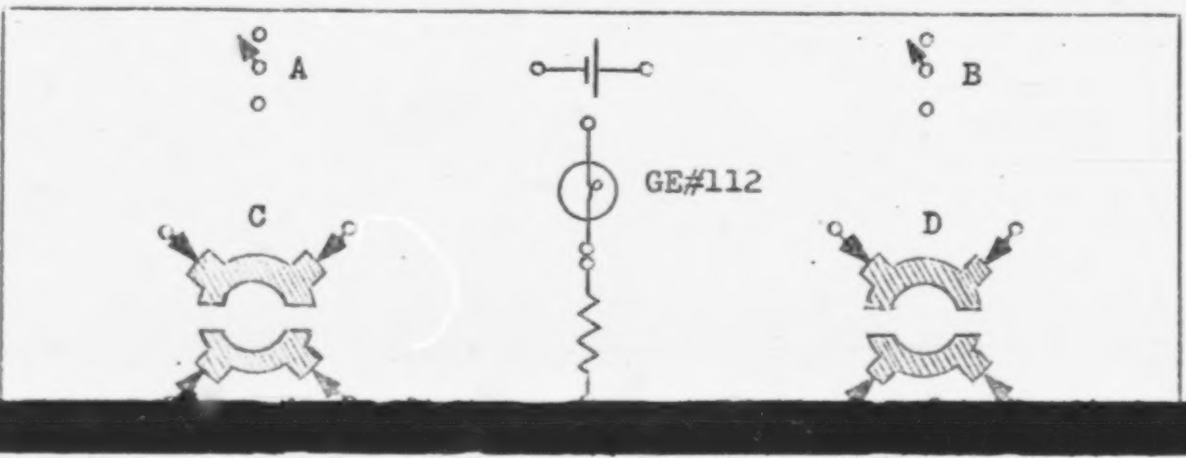
PROJECT I: Bulb controlled by switch A--on and off.

PROJECT II: Bulb controlled by switch B--bright and dim.

PROJECT III: Bulb controlled by two remote switches A and B--on and off.

PROJECT IV: Bulb controlled by three remote switches A,B,& C--on and off.

PROJECT V: Bulb controlled by four remote switches A,B,C,& D--on and off.



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PROBLEM: To design and construct electrical circuits satisfying prescribed specifications.

APPARATUS:

3 D batteries
2 rotary switches
6 pushbutton switches
2 SPDT switches
1 GE #112 bulb
1 lampbase
1 resistor
2 pegboards
4 buzzers
30 clip leads

REFERENCES:

PROCEDURE:

1. a) Design an electrical circuit satisfying the prescribed specifications for project I.
   -Make a neat freehand electrical schematic.
   b) Trace electron flow and verify:
   --that the battery is not short circuited by the wiring or switch positions.
   --that the circuit does satisfy the prescribed specifications.
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2. Repeat step #1 for the other projects.

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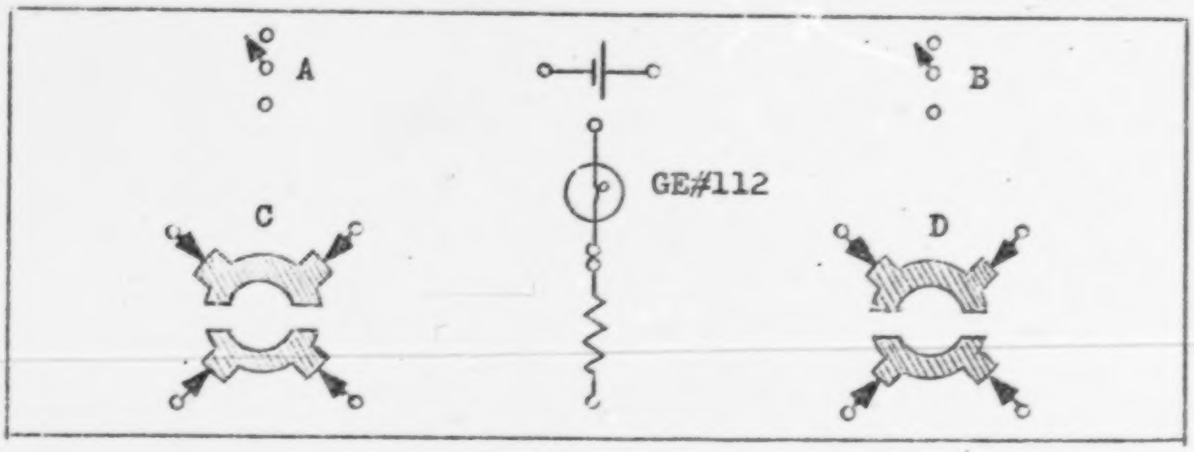
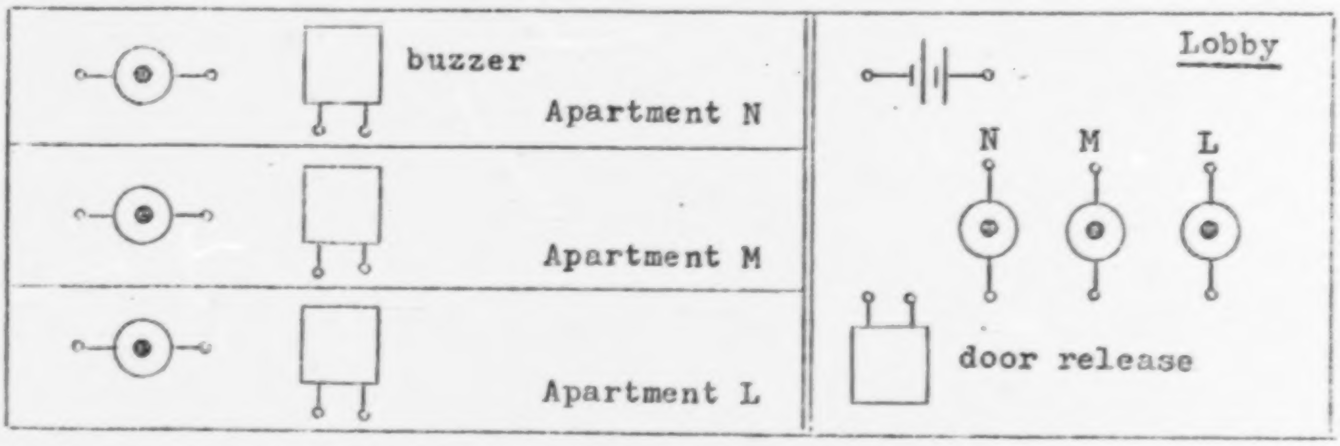
PROJECT IV: Bulb controlled by three remote switches A,B,& C--on and off.

PROJECT V: Bulb controlled by four remote switches A,B,C,& D--on and off.



PROJECT VI: Lobby buttons control buzzers in respective apartments and appartment buttons control door release in lobby.



Station

Exp.# 66

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Necessity is not the mother of invention; knowledge and experiment are its parents."
>
> W. R. Whitney
>
> "I never did anything worth doing by accident, nor did any of my inventions come by accident; they came by work.
>
> Thomas A. Edison

PROBLEM: To design, construct, and check an ohmmeter.

APPARATUS:

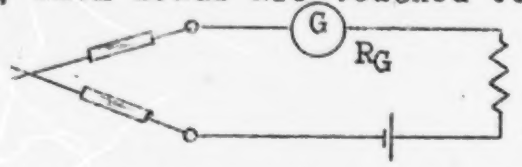
Cenco galvanometer
0-1.5v. voltmeter
Circuit board #8
60 ohm rheostat
1½v. battery
Worn 1½v. battery
Precision resistors
Compass
Scissors
Cardboard
Tape
Ruler

REFERENCES:

1. Philco, Basic Concepts and D.C. Circuits, pp. 117-21
2. U.S.N., Aviation Electrician's Mate, pp. 20-10,11
3. Gerrish, Electricity & Electronics, p. 157
4. Sears & Zemansky, University Physics, p. 658

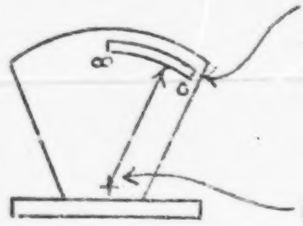
GATHERING THE DATA:

1. Measure battery voltage with the voltmeter.
   Caution: never connect battery directly across galvanometer
   1½ volts are more than enough to seriously damage a galvanometer.
2. Calculate series resistor required to yield full-scale galvanometer deflection, when leads are touched together.



(include galvanometer resistance in calculations)

3.



Cut-out cardboard dial and tape to meter.
--lightly mark with 50 divisions matching those on half the galvanometer dial. (place additional marks in the middle of each division for a total of 100 divisions--lightly identify each tenth division)

Center of galvanometer movement.

Note: zero ohms on right side of dial
"infinity" ohms at center of dial

4. Determine ohmmeter scale--carefully graduate it in ink according to table:

Resistance R (bet. probes)	$R_T = R_S + R_G + R$	E_B	$I_G = I_T = \frac{E_B}{R_T}$	Equivalent Scale Reading (on 100 div. scale) # div. = I_G x 4000
0			.025a	100
5				
100				
∞				0

5. Measure resistors on board #8 using ohmmeter.
   List measured resistances in a table.

SUMMATION:

they come by work.

Thomas A. Edison

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- 0-1.5v. voltmeter
- Circuit board #8
- 60 ohm rheostat
- 1½v. battery
- Worn 1½v. battery
- Precision resistors
- Compass
- Scissors
- Cardboard
- Tape
- Ruler

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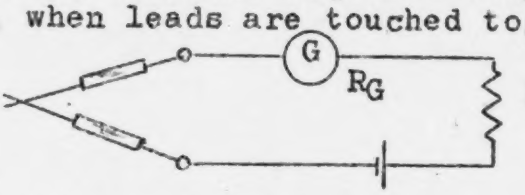

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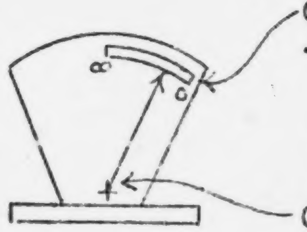

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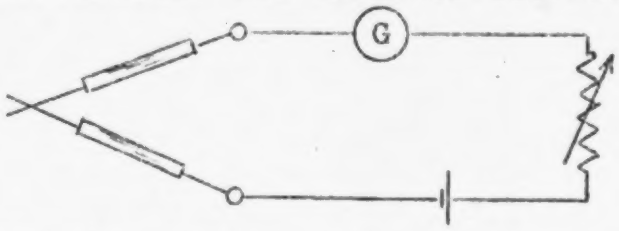
0			.025a	100
5				
100				
∞				0

5. Measure resistors on board #8 using ohmmeter.
   List measured resistances in a table.

SUMMATION:

1. How does ohmmeter dial differ from the usual voltmeter or ammeter dial?
2. What happens as battery runs down?
3. Reconstruct the ohmmeter with rheostat.



   a) Start with max. resistance and gradually adjust for zero with leads touching. Recheck resistances on circuit board #8.
   b) Insert worn battery & after again adjusting for zero, recheck resistors.
4. Has the meter's accuracy been affected? Explain.
5. Does the rheostat add to the practicality of the ohmmeter? Explain.
6. Justify: # divisions = $I_G \times 4000$.

Station ⬡ AVIATION HIGH SCHOOL Exp.# 67 APPLIED PHYSICS LABORATORY Team ○

> The mathematician may be compared to the designer of garments, who is utterly oblivious of the creature whom his garments may fit.. a shape will occasionally appear which will fit into the garment as if the garment had been made for it. Then there is no end of surprise and delight."
>
> Tobias Dantzig

PROBLEM: To apply Kirchhoff's Laws and simultaneous equations to electrical networks.

APPARATUS:

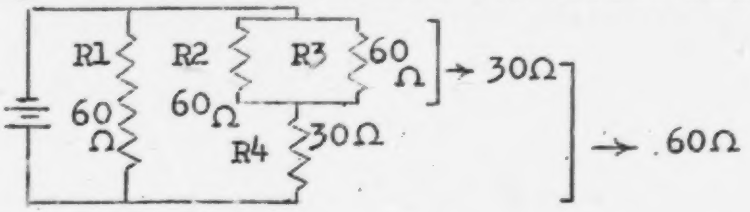
Weston ohmmeter
Resistance board #10
10 clip leads

REFERENCES:

1. Philco, Basic Concepts and D.C. Circuits, pp. 152-8
2. Sears, Electricity and Magnetism, pp. 129-30
3. Peck, Electricity and Magnetism, pp. 177-82

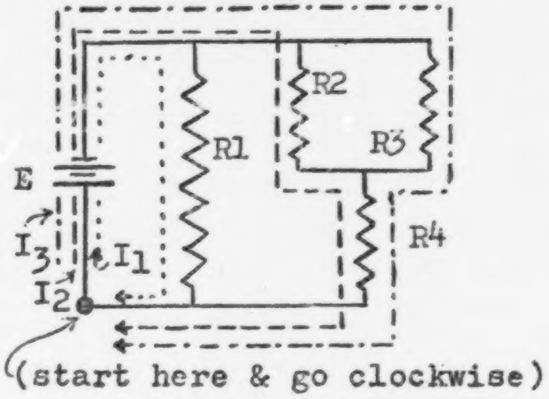
THEORY:

1. The total resistance of an electrical network can often be calculated by converting the network into an equivalent series-parallel circuit and applying the resistance rules for series and parallel circuits.



and the two remaining 60 ohm resistors in parallel have a total resistance of 30 ohms.

2. But sometimes a network cannot be converted into a combination of simple series and parallel circuits, and then Kirchhoff's law for loops affords a solution:



a) use loops with currents I_1, I_2, etc. such that every resistance is included at least once in one of the loops.

b) sum of voltage for each loop equals zero:

1) $-E + I_1R_1 = 0$
2) $-E + I_2(R_2+R_4) + I_3(R_4) = 0$
3) $-E + I_2(R_4) + I_3(R_3+R_4) = 0$

and substituting given resistance values:

1) $-E + 60I_1 = 0$
2) $-E + 90I_2 + 30I_3 = 0$
3) $-E + 30I_2 + 90I_3 = 0$

c) solve 2 and 3 simultaneously for I_2: $I_2 = \frac{E}{120}$

d) substitute this value in 2: $I_3 = \frac{E-90I_2}{30} = \frac{E}{120}$

e) solve 1 for I_1: $I_1 = \frac{E}{60}$

f) thus $I_t = I_1 + I_2 + I_3 = \frac{E}{60} + \frac{E}{120} + \frac{E}{120} = \frac{E}{30}$

g) and finally $E_t = I_tR_t$ $R_t = \frac{E}{E/30} = 30$ ohms

3. Wire circuit and check total resistance with ohmmeter.

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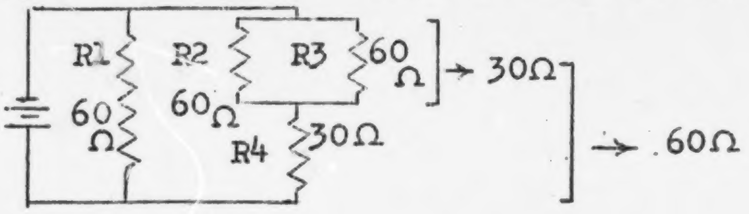

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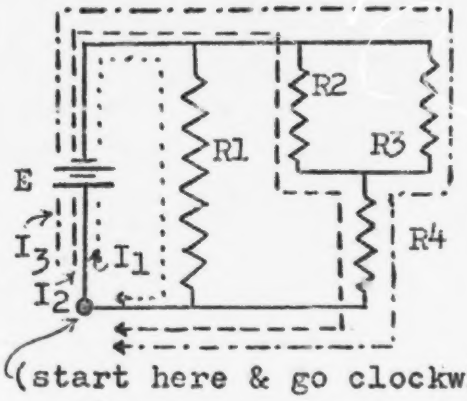

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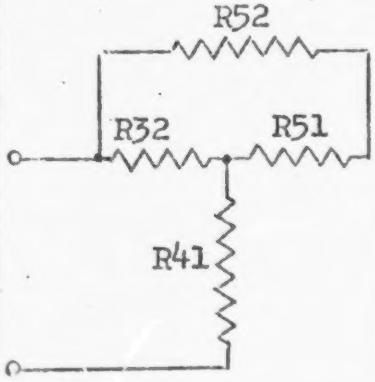
g) and finally $E_t = I_tR_t$ $\quad R_t = \frac{E}{E/30} = 30$ ohms

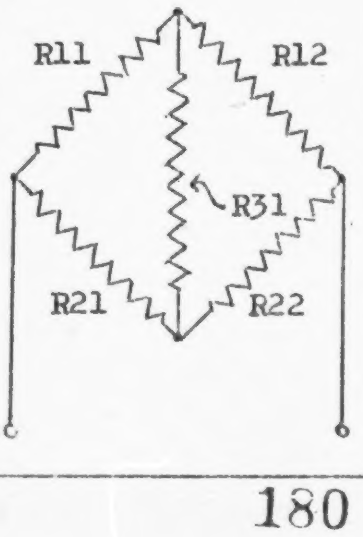
3. Wire circuit and check total resistance with ohmmeter.

APPLICATIONS: 1. a) measure and record individual resistances.
b) apply steps #1 and #2 where applicable to find R_t.
c) wire circuit and measure R_t -- resolve discrepancies!!

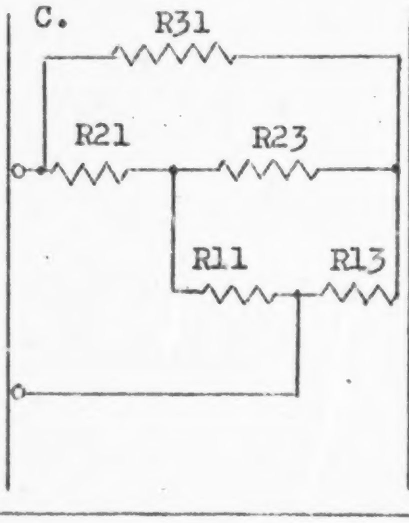
A.



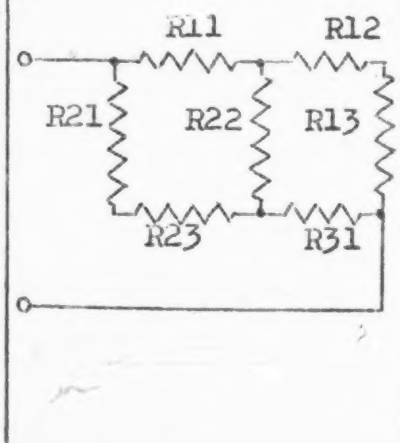
B.



C.



D.



Station   181 Exp.# 68   Team

AVIATION HIGH SCHOOL   APPLIED PHYSICS LABORATORY

> "If there is no other use discovered of electricity, this, however, is something considerable: that it may make a vain man humble."
>
> Benjamin Franklin

PROBLEM: To apply "T" and "π" transformations in circuit analysis.

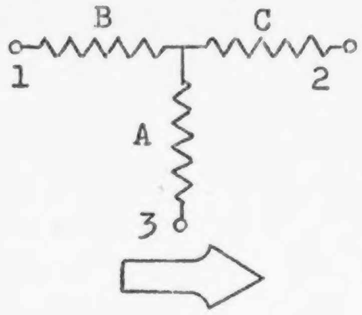
APPARATUS:

Ohmmeter	Cubical frame
Polyhedron models	Pegboard
Configuration boards	Leads
Precision resistor sets	

REFERENCES:

1. Peck, Electricity & Magnetism, p. 190
2. Courant, What Is Mathematics?, p. 237

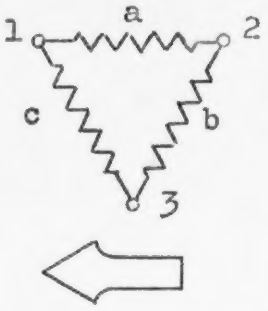
THEORY: T Pad --- may be transformed one into the other using: --- π Pad



$$A = \frac{bc}{a+b+c} \qquad a = \frac{AB+BC+CA}{A}$$

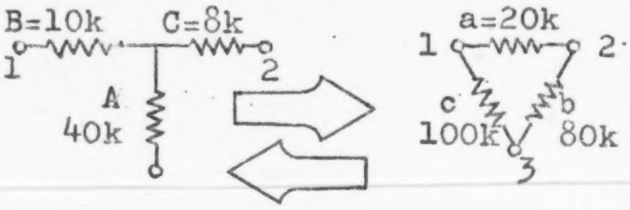
$$B = \frac{ac}{a+b+c} \quad \text{or} \quad b = \frac{AB+BC+CA}{B}$$

$$C = \frac{ab}{a+b+c} \qquad c = \frac{AB+BC+CA}{C}$$

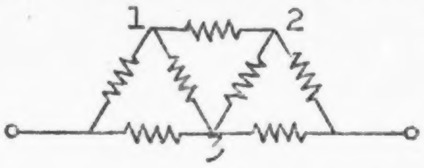


GATHERING THE DATA

1. a) Mathematically verify transformations --both ways.
   b) Wire circuits and verify practically.
   c) Resolve discrepancies.



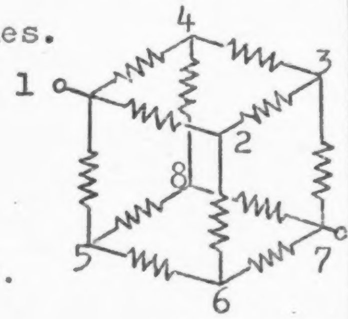
2. a) Calculate total circuit resistance using π to T transformations:



7k each resistor
Note: using R to represent each 7k resistance provides a general solution for equal resistors and simplifies work.

Hints: i) convert π pad 1, 2, 3, into a T pad.
ii) convert one of the resulting π pads into a T pad.
iii) determine the total resistance of series-parallel circuit resulting from ii.

b) Wire circuit, measure resistance and resolve discrepancies.

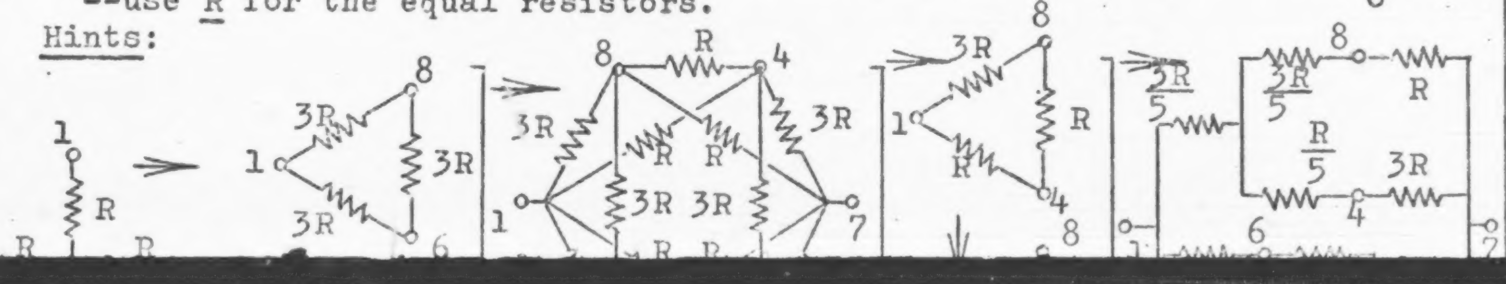


3. a) Measure total circuit resistance using several different sets of equal resistors.
   b) Plot graph.

for circuits tested & determine relationship between R_T and R.

   c) Calculate total resistance using π and T transformations. --use R for the equal resistors.

Hints:



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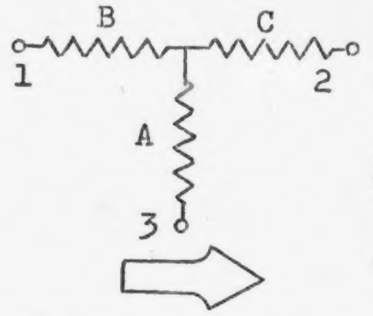

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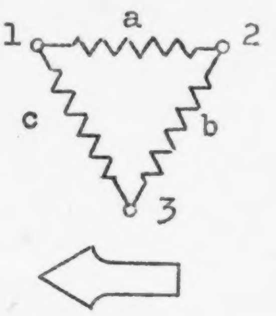
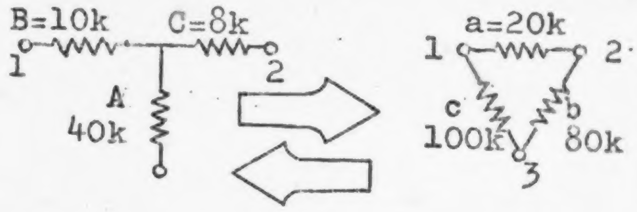
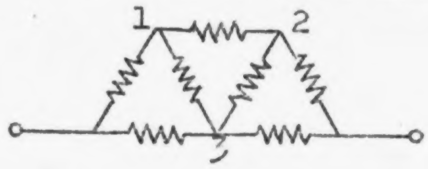


GATHERING THE DATA


B=10k
C=8k
1
2
A
40k
a=20k
1
2
c
b
100k
80k
3

1. a) Mathematically verify transformations --both ways.
   b) Wire circuits and verify practically.
   c) Resolve discrepancies.

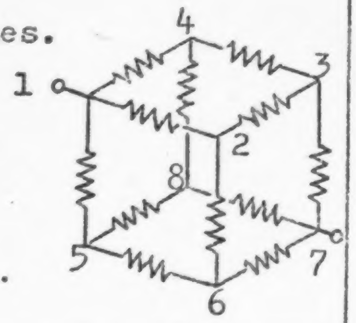
2. a) Calculate total circuit resistance using π to T transformations:



7k each resistor
Note: using R to represent each 7k resistance provides a general solution for equal resistors and simplifies work.

Hints: i) convert π pad 1, 2, 3, into a T pad.
ii) convert one of the resulting π pads into a T pad.
iii) determine the total resistance of series-parallel circuit resulting from ii.

   b) Wire circuit, measure resistance and resolve discrepancies.



3. a) Measure total circuit resistance using several different sets of equal resistors.
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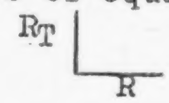

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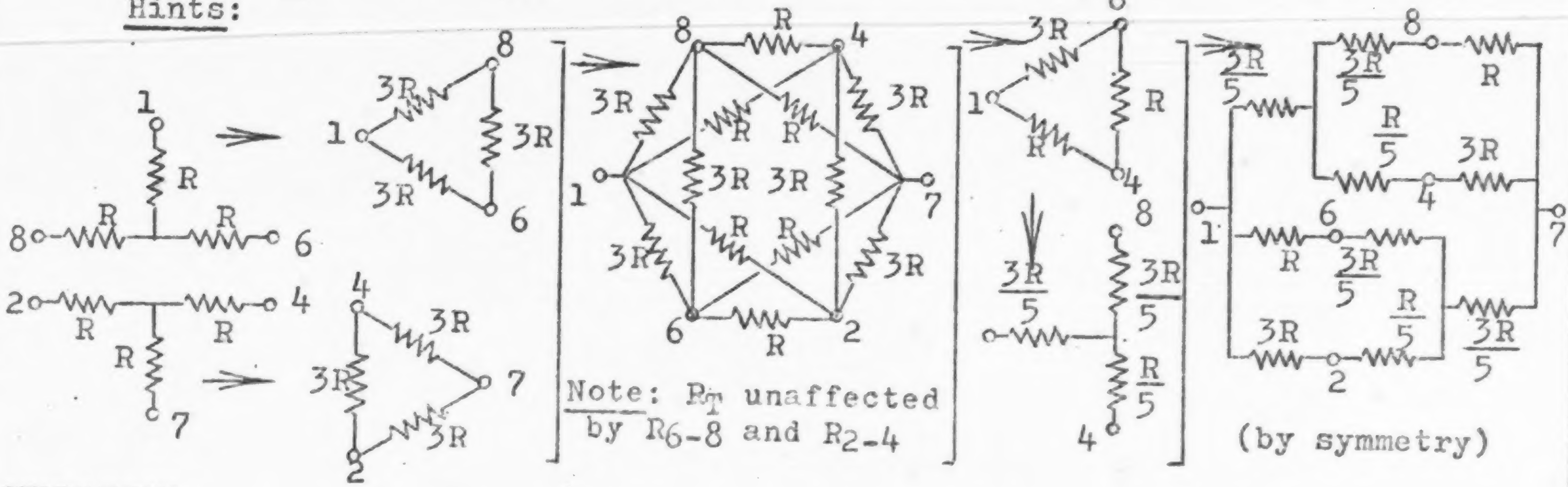
Hints:


1
R
8
R
R
6
8
3R
1
3R
3R
6
2
R
4
R
R
7
4
3R
3R
7
3R
2
8
R
4
3R
3R
1
R
R
3R
3R
7
R
R
3R
3R
6
R
2
8
3R
1
R
R
4
8
3R/5
3R/5
3R/5
R/5
4
3R/5
3R/5
8
R
R/5
3R
4
1
7
6
R
3R/5
R/5
3R/5
3R
2
(by symmetry)

Note: R_T unaffected by R_{6-8} and R_{2-4}

SUMMATION:

1. Why is R_T unaffected by R_{6-8} and R_{2-4} in 3c of GATHERING THE DATA?
2. Prove that the equations given in THEORY are applicable to all T and π transformations.
3. Calculate the total resistances of the following polyhedra with equal resistances R connected between vertices:
   a) octahedron
   b) icosahedron
   c) dodecahedron

Station

Exp.# 69

AVIATION HIGH SCHOOL

APPLIED PHYSICS LABORATORY

Team

> "The moving power of mathematical invention is not reasoning but imagination."
>
> Augustus De Morgan
>
> "We repeat, there was far more imagination in the head of Archimedes than in that of Homer."
>
> Voltaire

PROBLEM: To determine the total resistance of equal resistors in regular polyhedron configurations using Kirchhoff's Laws.

APPARATUS:

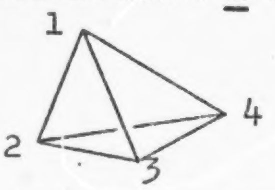
Ohmmeter
Peg board
Polyhedron models
Leads
Configuration boards
Precision resistor sets

REFERENCES:

1. Courant, What is Mathematics?, pp. 235-7
2. Timbie, Basic Electricity for Communications, p. 117

THEORY: To determine the total resistance of equal resistances R connected between the vertices of a tetrahedron:

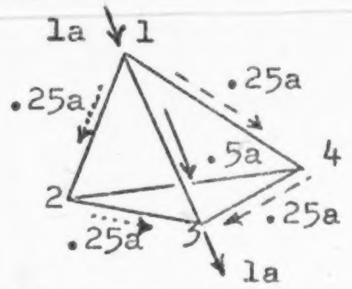
a) Number the vertices



b) If the resistance between 1 and 3 is desired, assume that 1 is at a higher potential and assume that the total current $I_T = 1$ ampere.

c) Determine the number and difficulty of paths from 1 to 3.

d) Apportion current according to path difficulty and Kirchhoff's current law applied to the branch points:



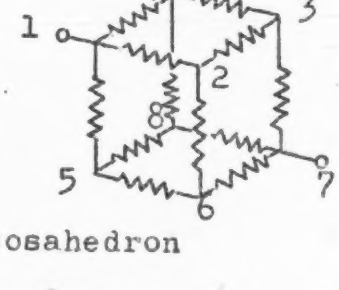
Note: No current from 2 to 4

e) $E_{1-3} = E_T = I_{1-3}R$

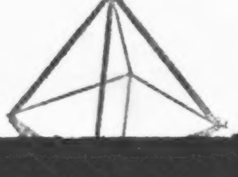
f) $R_T = \frac{E_T}{I_T} = \frac{0.5R}{1} = 0.5R$

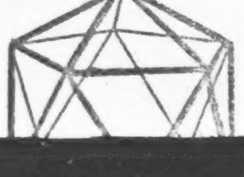
GATHERING THE DATA:

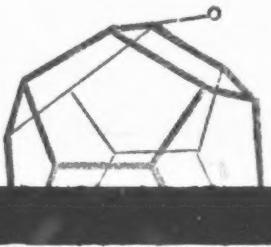
1. a) Wire equal resistances in a tetrahedron configuration and measure the actual resistance.
   b) Repeat a for other sets of equal resistances.
2. a) Determine the total resistance of equal resistances R connected between the vertices of a hexahedron.
   b) Wire circuit using set of equal resistances, measure resistance and resolve discrepancies.



3. Repeat step #2 for:
   a) octahedron
   b) icosahedron
   c) dodecahedron







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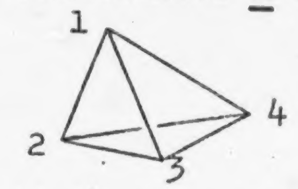

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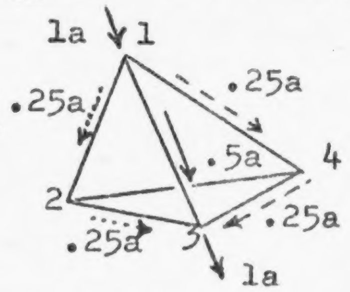
c) Determine the number and difficulty of paths from 1 to 3.

d) Apportion current according to path difficulty and Kirchhoff's current law applied to the branch points:



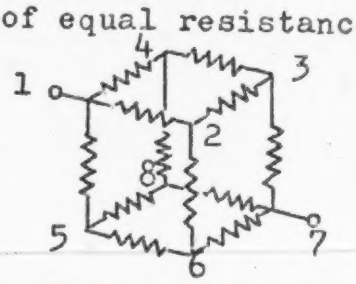
Note: No current from 2 to 4

e) $E_{1-3} = E_T = I_{1-3}R$

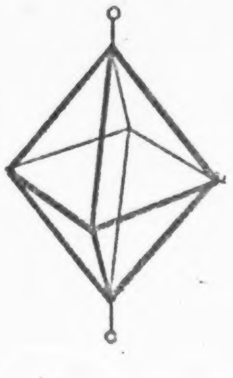
f) $R_T = \dfrac{E_T}{I_T} = \dfrac{0.5R}{1} = 0.5R$

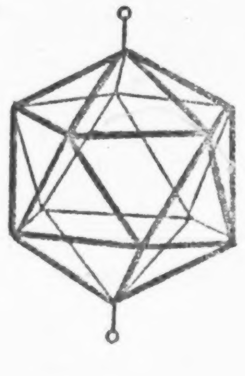
GATHERING THE DATA:

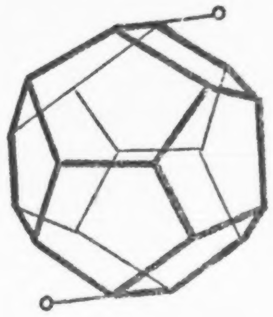
1. a) Wire equal resistances in a tetrahedron configuration and measure the actual resistance.
   b) Repeat a for other sets of equal resistances.
2. a) Determine the total resistance of equal resistances R connected between the vertices of a hexahedron.
   b) Wire circuit using set of equal resistances, measure resistance and resolve discrepancies.



3. Repeat step #2 for:
   a) octahedron
   b) icosahedron
   c) dodecahedron







SUMMATION:

1. Justify the note in step d THEORY: "No current from 2 to 4".
2. Given unequal resistances connected between the vertices of polyhedra;
   a. explain how the total resistances can be calculated.
   b. explain why the method used in this experiment may not be readily applicable.

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

"According to Professor P. G. Tait, who worked with him, Joule gave the ou in his name the sound of ou in you."

Joseph O. Thompson

"The person who won't take advice isn't necessarily any more stubborn than the one who is offering it."

Anon.

PROBLEM: To measure electrical power and work, and to quantitatively examine the conversion of electrical energy into heat.

APPARATUS:

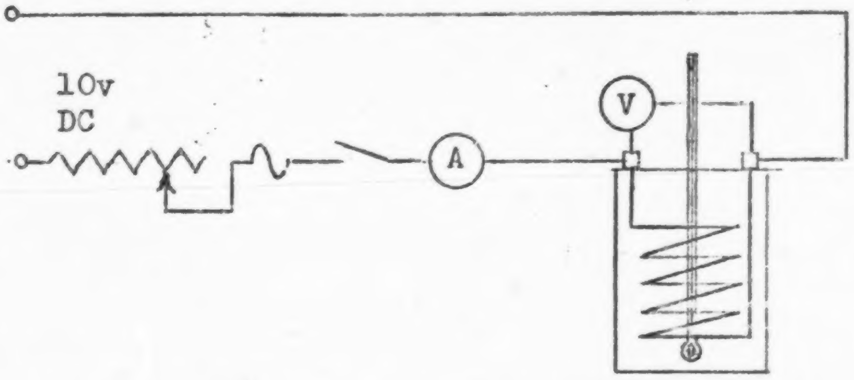
Electrical calorimeter
5a. ammeter
0-15v. voltmeter
5a. fuse & holder
SPST switch
Peg board
Thermometer
Ohaus triple beam balance
Stop watch
15 clip leads
Potentiometer
Ice
Plastic funnel

REFERENCES:

1. Holton, Found. of Mod. Physical Science, pp. 348-51
2. White, Modern College Physics, pp. 431-3
3. Stollberg, Foundations of Physics, pp. 266-7, pp. 272-3, pp. 424-6
4. MacLachlan, Matter & Energy, pp. 156-9

GATHERING THE DATA:

1. a) Hook-up electrical circuit, set rheostat for min. voltage--do not close switch.



Water Equivalents:

calorimeter 16.1 gm
leads, stirrer & coil 2.5 gm

b) Measure mass of calorimeter (inner container)
c) Cool water and calorimeter to 10 C° (or 15 C°) below room temperature.
d) Fill calorimeter with sufficient water to cover coil.
--measure mass of water.
e) Insert coil and thermometer, note starting temp., close switch, and begin timing--adjust potentiometer for constant 4a & note voltage.
f) Record temperature, current, voltage, & total time for every minute until water temperature reaches 10C° (or 15C°) above room temperature.
--gently stir water before each reading.

Time (seconds)	E	I	C
0		4a	
etc.		4a	

2. a) Calculate total calories added to the water, calorimeter, leads, stirrer,

> "The person who wont take advice isn't necessarily any more stubborn than the one who is offering it."
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Thermometer
Ohaus triple beam balance

Stop watch
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Ice
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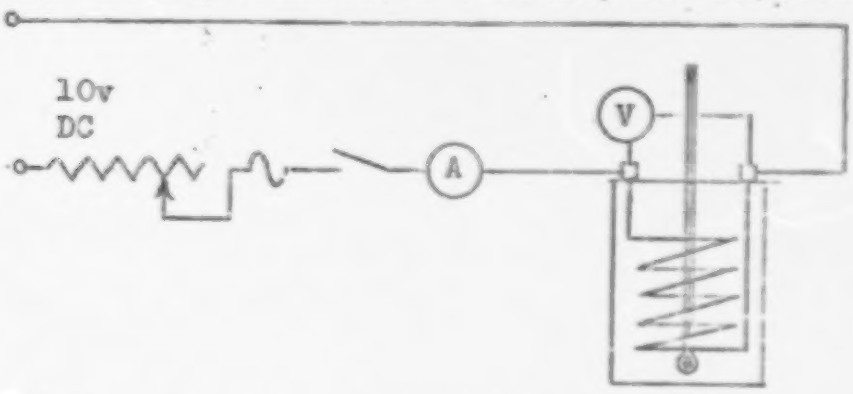

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   --gently stir water before each reading.

Time (seconds)	E	I	C
0		4a	
etc.		4a	

2. a) Calculate total calories added to the water, calorimeter, leads, stirrer, and coil.
   b) Calculate the electrical work in watt·sec. (use mean voltage)
   c) Determine rate at which electrical evergy is supplied.
   d) Determine the % difference between calculations of a and b.

SUMMATION:

1. Why is calorimetry process started below room temp. and concluded above?
2. What does "water equivalent" mean? How does it help?
3. Show that electrical work = watt · sec.
4. How much electrical power was involved?
5. According to experimental results:
   a) what is "Joule's Equivalent"?
   b) how much will 1 watt·sec. raise the temp. of 1 gm of water?

Station ⬡ **AVIATION HIGH SCHOOL** Exp.# 71 **APPLIED PHYSICS LABORATORY** Team ○

> "The study of thermodynamics started with Carnot's interest in steam engines. Pasteur's science of bacteriology began when he tried to prevent French beer and wine manufacturers' products from turning sour. Group theory was invented by Galois as a means of studying the properties of algebraic equations. So to speak, nearly every 'pure' science starts as an 'applied', or at least as an extrinsically motivated, science."
>
> Alvin Weinberg

PROBLEM: To experimentally determine and apply the temperature coefficient of electric resistance.

APPARATUS:

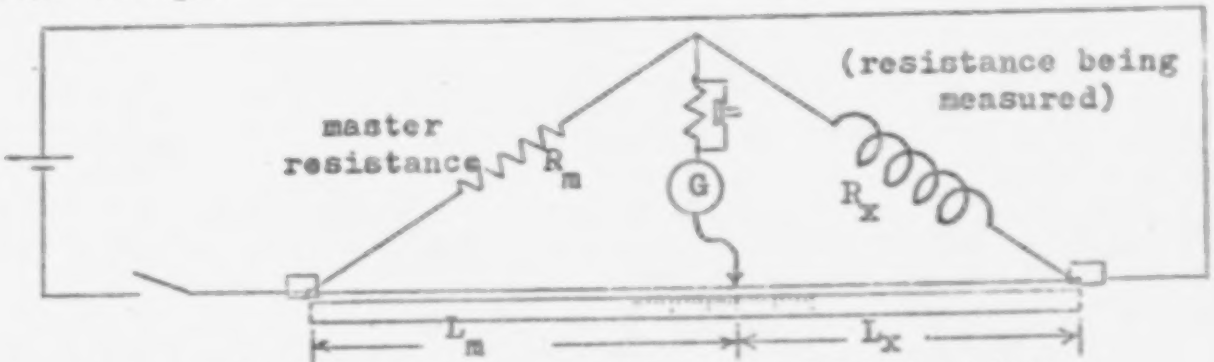
0-250 microammeter
Master resistances
Potentiometer
Transformer
Bunsen burner
Hot plate coil
1000cc beaker
Thermometer & stand
Slide wire Wheatstone bridge
Wire coil
#6 battery
10 clip leads
Motor
SPST switch
Ice

REFERENCES:

1. Van Valkenburgh, Basic Electricity, pp. 1-105
2. Philco, Basic Concepts Vol. I, pp. 51-2
3. Halliday & Resnick, Physics, pp. 685-6
4. Sears & Zemansky, Univ. Physics, pp. 617-20

GATHERING THE DATA:

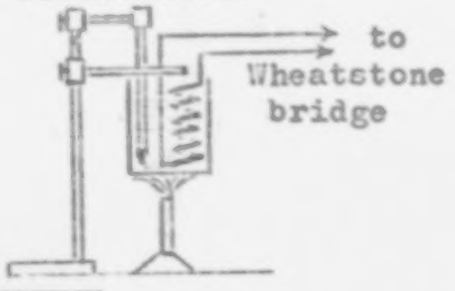
1. Set up Wheatstone bridge:



2. Measure the resistances of wire coil, transformer primary, & motor. Associate and record room temperature with each resistance measured. (Use appropriate master resistance--one which results in null near center of slidewire)

Note: $R_x = \frac{L_x}{L_m} \cdot R_m$

3. Plug transformer and motor into 110v AC. Operate both for approximately one-half hour, and then remeasure (quickly) their resistances.



4. a) Place wire coil in ice water and measure its resistance and temperature when it is at thermal equilibrium with the ice water.
   b) Heat slowly--permitting water and coil to closely approach thermal equilibrium as temperature increases.
   c) Take temperature and resistance readings at 5° temperature intervals.
   d) Record data in table.
   e) Plot graph.
   f) Calculate the temperature coefficient of

Temp.	R_c
5 C	

ohms

> studying the properties of algebraic equations. So to speak, nearly every 'pure' science starts as an 'applied', or at least as an extrinsically motivated, science."
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PROBLEM: To experimentally determine and apply the temperature coefficient of electric resistance.

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Master resistances	#6 battery
Potentiometer	10 clip leads
Transformer	Motor
Bunsen burner	SPST switch
Hot plate coil	Ice
1000cc beaker	
Thermometer & stand	
Slide wire Wheatstone bridge	

REFERENCES:

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GATHERING THE DATA:

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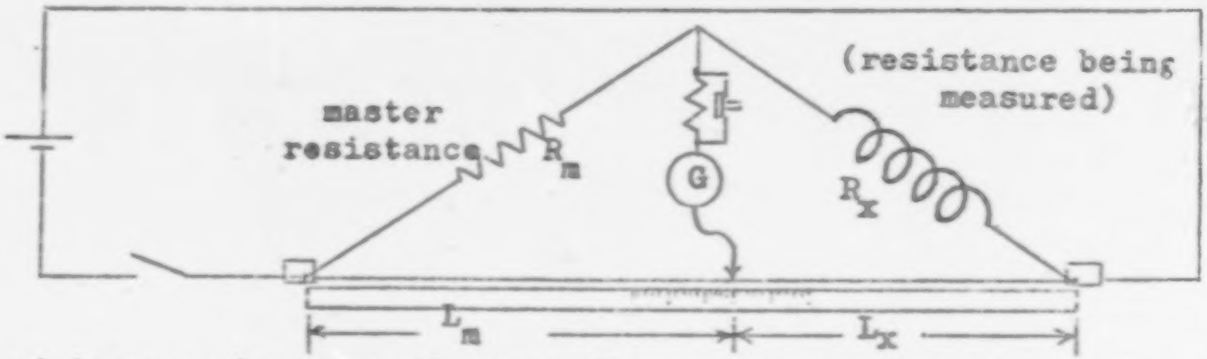

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   Note: $R_x = \frac{L_x}{L_m} \cdot R_m$

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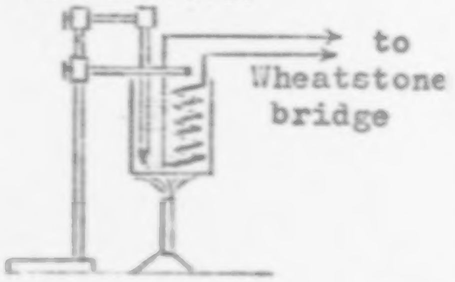
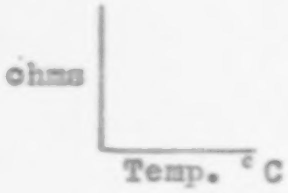
   c) Take temperature and resistance readings at 5° temperature intervals.
   d) Record data in table.
   e) Plot graph.
   f) Calculate the temperature coefficient of electric resistance:



Temp.	R_c
5 C	
100 C	



$$\alpha = \frac{\Delta R}{R} \cdot \frac{1}{\Delta t}$$

(Res. at final temp.) (Change in temp.)

SUMMATION:

1. Determine operating temperatures of:
   a) the transformer
   b) the motor

   Apply $\alpha = \frac{\Delta R}{R} \cdot \frac{1}{\Delta t}$

2. Determine the operating temperature of the hot plate:
   a) measure resistance of the cold hot plate.
   b) plug hot plate into 110v AC and allow to heat thoroughly.
   c) unplug and quickly measure resistance.
   d) apply temperature coefficient equation and the temperature coefficient of electric resistance of nichrome wire.

Station

Exp.# 72

Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "The story of physics...must be gained in the laboratory where the phenomena themselves are seen and felt and heard and the ultimate incontrovertible authority of experiment is manifest...we must learn our science each of us individually from nature herself."
>
> Gaylord P. Harnwell

PROBLEM: To determine circuit conditions for maximum power transfer.

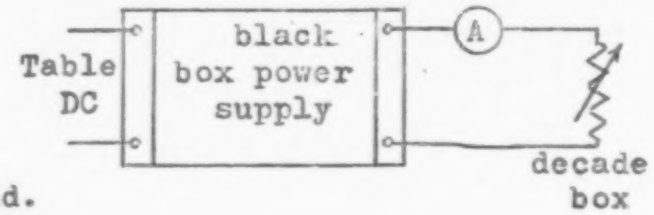
APPARATUS:

- Microammeter
- Decade resistance box
- Semi-logarithmic paper
- Peg board & Black box power supply
- VTVM
- Leads

REFERENCES:

1. Timbie, Basic Electricity for Communications, pp. 121-3
2. Brophy, Basic Electronics for Scientists, pp. 33-4

GATHERING THE DATA:



1. Wire circuit as shown:
2. Determine load power for various loads.
    a) measure microamps for 200 ohm load.
    b) calculate microwatts for 200 ohm load.
    c) repeat a & b for loads listed in table:

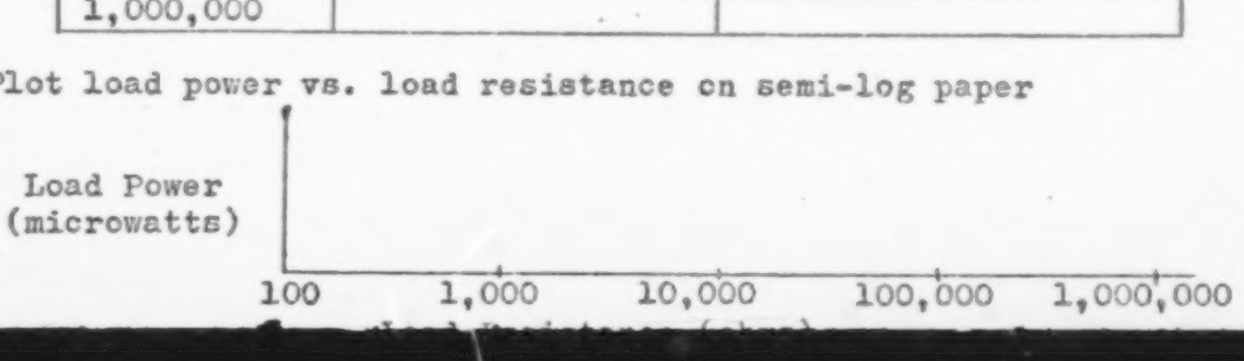
R_L (ohms)	I_L (microamps)	$P = I^2R$ (microwatts)
200		
400		
600		
800		
1,000		
2,000		
4,000		
6,000		
8,000		
10,000		
20,000		
40,000		
60,000		
80,000		
100,000		
200,000		
400,000		
600,000		
800,000		
1,000,000		

alternatively*

$P = \frac{E^2}{R}$

(include meter resistance as part of load --especially for small loads)

3. Plot load power vs. load resistance on semi-log paper



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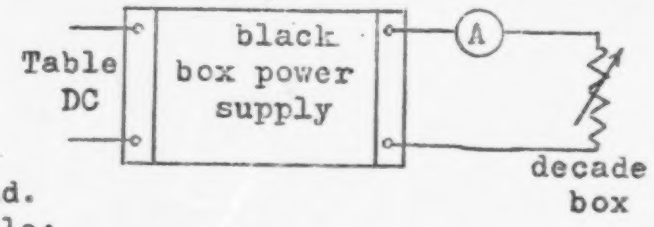

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200		
400		
600		
800		
1,000		
2,000		
4,000		
6,000		
8,000		
10,000		
20,000		
40,000		
60,000		
80,000		
100,000		
200,000		
400,000		
600,000		
800,000		
1,000,000		

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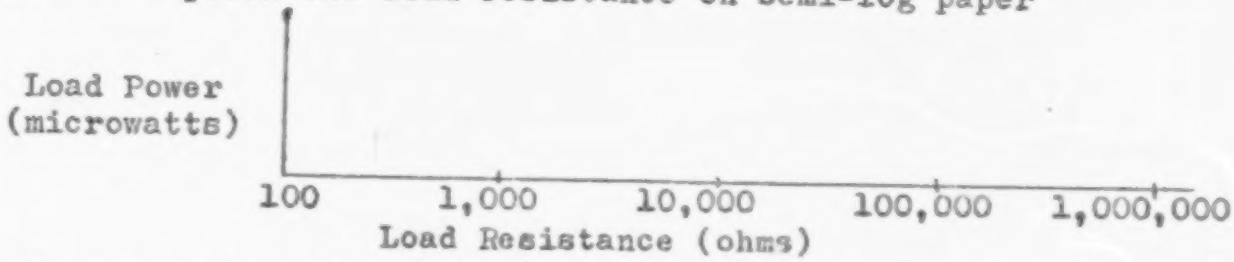


4. Determine internal resistance of black box power supply: $R = \frac{E \text{ (no load)}}{I \text{ (short ckt)}}$

SUMMATION:

1. According to experimental evidence, what is the relationship between supply's internal resistance & load resistance when load power a maximum.
2. Open black box & check supply voltage and internal resistance.
3. Using calculations, check generality of step #1 conclusion for:
   a) 5v supply with R (internal) = 100 ohms.
   b) 100v supply with R (internal) = 20 ohms.
4. a) Why was graph plotted on semi-logarithmic paper rather than o graph paper?
   b) A disadvantage of the logarithmic scale is that it cannot zero. Neither the logarithmic scale nor the slide rule sc with it contains zero. Explain.
5. Mathematically demonstrate that the power received by the when load resistance equals supply resistance.

Station ⬡ Exp.# 73 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Although the student will not believe this at the outset, a general problem is often more readily solved than a specific one. To quote a saying of a great American scientist, J. Willard Gibbs--'The whole is simpler than its parts'."
>
> Louis Brand

PROBLEM: To apply Thevénin's Theorem to "complex" black box circuits.

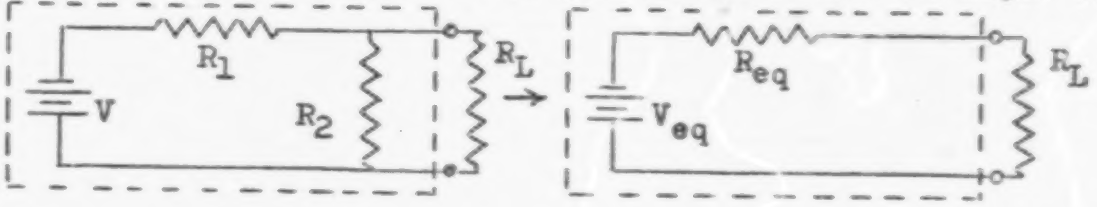
APPARATUS:

VTVM	Leads
Ohmmeter	Resistor set
Peg board & Black box	
Peg board & Adj. Constant Voltage Box	

REFERENCES:

1. Brophy, Basic Electronics for Scientists, pp. 29-30
2. Timbie, Basic Electricity for Communications, pp. 128-32

THEORY: Any two terminal network can be replaced by an equivalent series circuit consisting of a single resistor and a single voltage source.



where:

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$V_{eq} = V \frac{R_2}{R_1 + R_2}$$

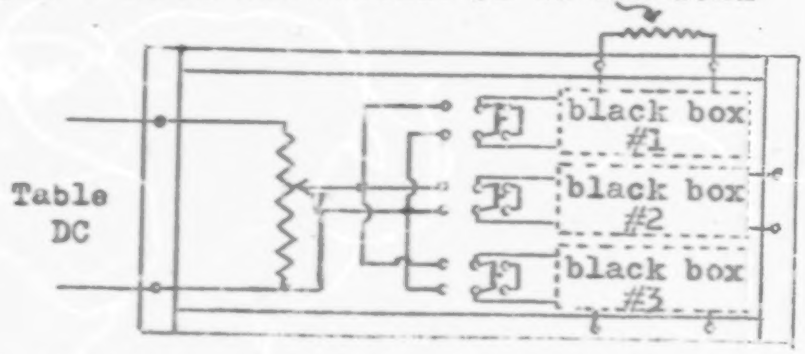
GATHERING THE DATA:

.. a) Connect black box to table supply & black box circuit #1 to 10k load.

b) Activate momentary switch for black box #1 & adjust voltage V_L across 10k load for 1v.

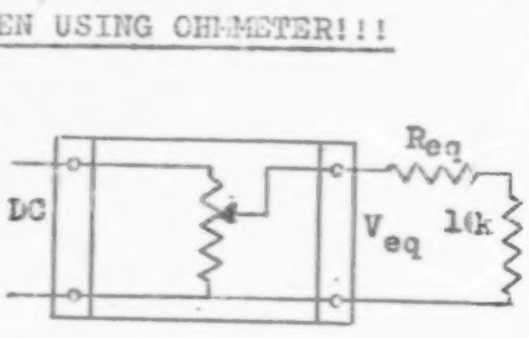
c) Determine V_{eq} by measuring no-load voltage of black box #1.

d) Determine R_{eq} by measuring no-load resistance of black box #1.



Note: MOMENTARY SWITCH MUST NOT BE ACTIVATED WHEN USING OHMMETER!!!

2. Wire equivalent circuit.
   --keep adj. constant voltage source at 0 volts until circuit is completely wired and then accurately adjust V_{eq}.



3. Measure V_L across load of equivalent circuit & verify correspondence with voltage V_L across black box load.

4. Repeat steps #1, 2, and 3 for:
   - a) black box #2 with 18k load and $V_L = 0.9$v
   - b) black box #3 with 4k load and $V_L = 1.6$v

5. After teacher verifies successful application of Thévenińs Theorem to black boxes #1, 2, and 3, open black box and:
   - a) make schematic of circuit #1
   - b) using actual black box components and no-load, calculate R_{eq} at black box output terminals.
     (momentary switch normally connects circuit to short)

PROBLEM: To apply Thevénin's Theorem to "complex" black box circuits.

APPARATUS:

VTVM Leads
Ohmmeter Resistor set
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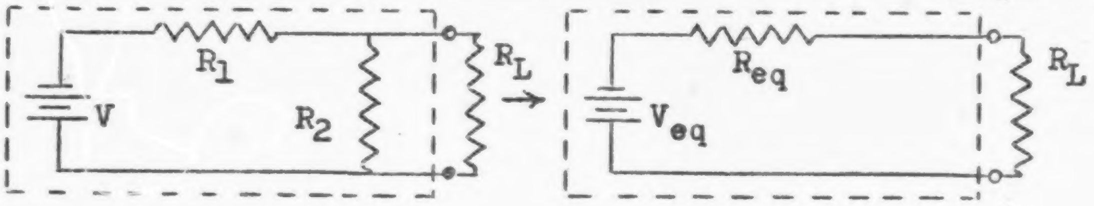

where:

$$R_{eq} = \frac{R_1 R_2}{R_1+R_2}$$

$$V_{eq} = V\frac{R_2}{R_1+R_2}$$

GATHERING THE DATA:

1. a) Connect black box to table supply & black box circuit #1 to 10k load.
   b) Activate momentary switch for black box #1 & adjust voltage V_L across 10k load for 1v.
   c) Determine V_{eq} by measuring no-load voltage of black box #1.
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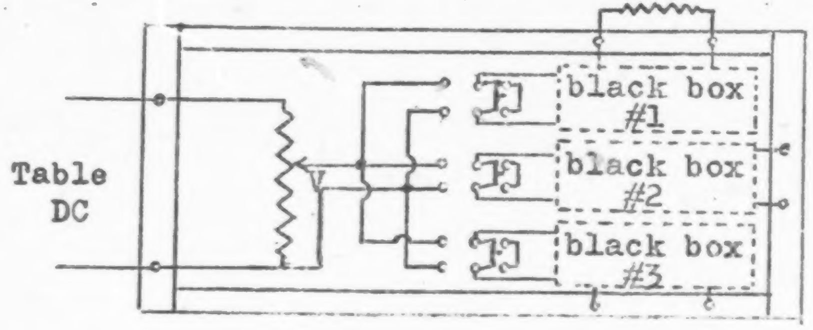

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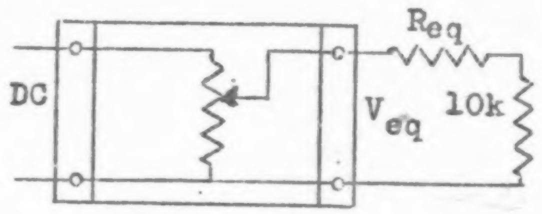

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   b) black box #3 with 4k load and V_L = 1.6v

5. After teacher verifies successful application of Thévenins Theorem to black boxes #1, 2, and 3, open black box and:
   a) make schematic of circuit #1
   b) using actual black box components and no-load, calculate R_{eq} at black box output terminals.
      (momentary switch normally connects circuit to short)
   c) activate momentary switch of black box #1 and as before adjust for 1v across 10k load. Measure V. Using actual black box components and no-load, justify V_{eq} value.
      (activated momentary switch replaces short with supply voltage V)
   d) sketch equivalent series circuit with R_{eq} & V_{eq} and calculate V_L.
   e) if theory and practice do not agree, resolve difficulty.

6. Repeat step #5 for black boxes #2 and #3 using corresponding loads and voltages as given in step #4.

SUMMATION:

1. Provide general development of Thévenin's Theorem.
   --supply missing "obvious" steps in Brophy's development pp. 29-30.
2. Apply general development to black boxes #1, 2, and 3.

Station

AVIATION HIGH SCHOOL Exp.# 74 APPLIED PHYSICS LABORATORY

Team

> "The results of observation or tests usually are plotted in a curve.. When plotting from numerical observations, the curves are empirical, and the first and most important problem which has to be solved to make such curves useful is to find equations for the same, that is, find a function, y = f(x), which represents the curve. As long as the equation of the curve is not known its utility is very limited. While numerical values can be taken from the plotted curve, no general conclusion can be derived from it...."
>
> Charles P. Steinmetz

PROBLEM: To investigate and design L-Pads.

APPARATUS:

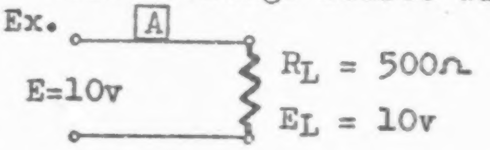
VTVM & Milliammeter
Mallory variable L-Pad
2 momentary switches
Constant voltage pot.& fuse
20 clip leads
10k rheostat
Pegboard
Precision R.

REFERENCES:

1. Timbie, Basic Electricity for Comm. pp. 39-41
2. Steinmetz, Engineering Math. pp. 216-25; 233-35

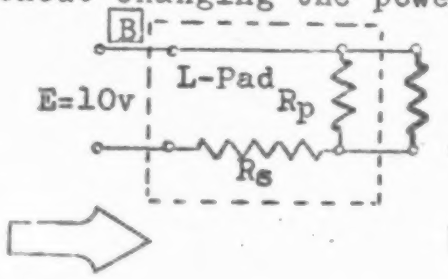
THEORY: An L-Pad will change the voltage of a load connected across a constant voltage source without changing the power drawn from the source.

Ex.



$I_L = \frac{E_L}{R_L} = \frac{10}{500} = 0.02a$

$P = \frac{E_L^2}{R_L} = \frac{100}{500} = 0.2$ watts



$R_L = 500\Omega$ & want $E_L = 8v$

a) $I_L = \frac{E_L}{R_L} = \frac{8}{500} = 0.016a$

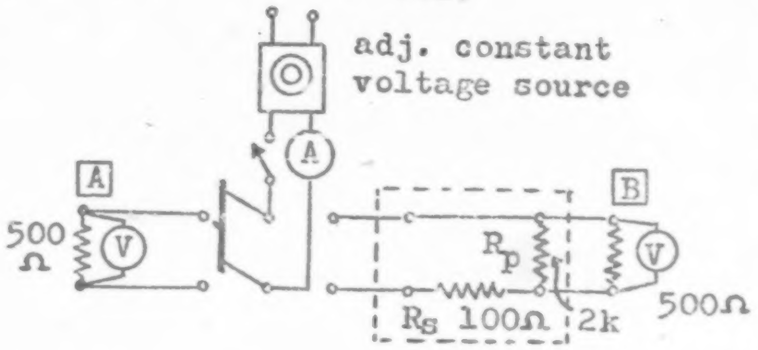
b) $I_p = 0.004a \quad R_p = 2000\Omega$

c) $E_s = E - E_L = 2v$

d) $R_s = \frac{E_s}{I_s} = \frac{2}{.020} = 100$ ohms

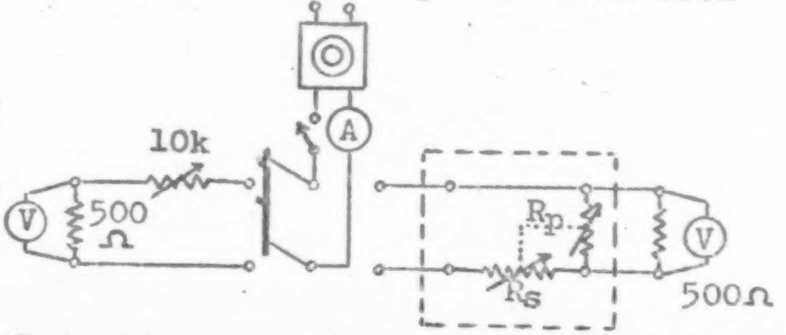
GATHERING THE DATA:

1. a) Wire circuit A & adjust constant voltage source for 10v. across 500 ohm load.
   b) Wire circuit B & without disturbing 10v. setting, verify that the voltage across the 500 ohm load is 8v. and that the power drawn from the source is unchanged.



2. Design & test, as in step #1, an L-Pad which will change a 10v. supply voltage to 9v. across the 500 ohm load without change in power drawn from the source.

3. a) Connect variable L-Pad across source & load, and check its ability to continuously change load voltage from 0 to 10v. with power unchanged.
   b) Compare L-Pad control with that of an ordinary 10k rheostat placed in series with the load.



4. a) Completely disconnect variable L-Pad and as its adjustment knob is varied in 10 equal steps from 0 to 100, measure & record the corresponding individual resistances

curve is not known its utility is very limited. While numerical values can be taken from the plotted curve, no general conclusion can be derived from it...."

Charles P. Steinmetz

PROBLEM: To investigate and design L-Pads.

APPARATUS:

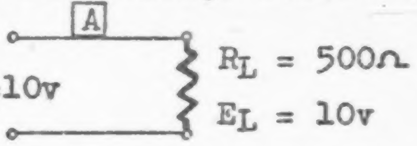
VTVM & Milliammeter
Mallory variable L-Pad
2 momentary switches
Constant voltage pot.& fuse
20 clip leads
10k rheostat
Pegboard
Precision R.

REFERENCES:

1. Timbie, Basic Electricity for Comm. pp. 39-41
2. Steinmetz, Engineering Math. pp. 216-25; 233-35

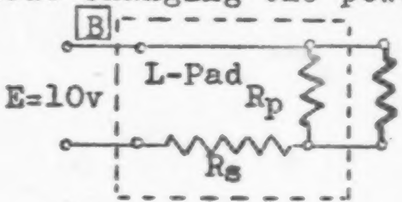
THEORY: An L-Pad will change the voltage of a load connected across a constant voltage source without changing the power drawn from the source.

Ex.



$$I_L = \frac{E_L}{R_L} = \frac{10}{500} = 0.02a$$

$$P = \frac{E_L^2}{R_L} = \frac{100}{500} = 0.2 \text{ watts}$$



R_L = 500Ω & want E_L = 8v

a) $I_L = \frac{E_L}{R_L} = \frac{8}{500} = 0.016a$

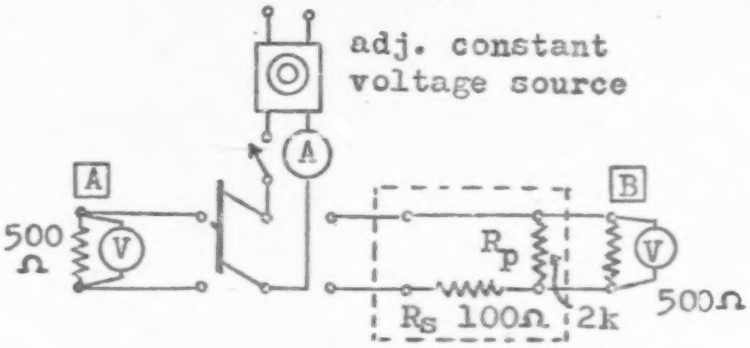
b) $I_p = 0.004a$ $R_p = 2000Ω$

c) $E_s = E - E_L = 2v$

d) $R_s = \frac{E_s}{I_s} = \frac{2}{.020} = 100$ ohms

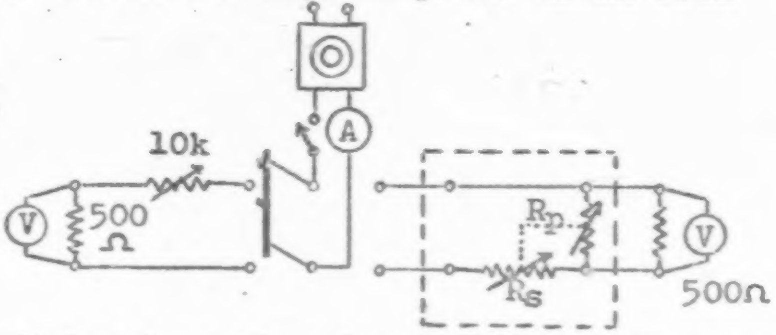
GATHERING THE DATA:

1. a) Wire circuit A & adjust constant voltage source for 10v. across 500 ohm load.
   b) Wire circuit B & without disturbing 10v. setting, verify that the voltage across the 500 ohm load is 8v. and that the power drawn from the source is unchanged.



2. Design & test, as in step #1, an L-Pad which will change a 10v. supply voltage to 9v. across the 500 ohm load without change in power drawn from the source.

3. a) Connect variable L-Pad across source & load, and check its ability to continuously change load voltage from 0 to 10v. with power unchanged.
   b) Compare L-Pad control with that of an ordinary 10k rheostat placed in series with the load.



4. a) Completely disconnect variable L-Pad and as its adjustment knob is varied in 10 equal steps from 0 to 100, measure & record the corresponding individual resistances of R_s and R_p.
   b) Plot R_s vs. dial setting.
   c) Plot R_p vs. dial setting.
   d) Identify the equations of the curves.

SUMMATION:

1. What evidence shows that the power drawn from the source is unchanged in steps #1, #2, and #3 of GATHERING THE DATA.
2. Analytically determine the R_s vs. R_p curve (equivalent to curve in 4c):
   a) In accordance with L-Pad requirements, equate R_L and the combined resistance of the L-Pad and R_L.
   b) Manipulate the terms until R_s and R_p are on opposite sides of equation. (R_L a constant)
   c) Study the relation between variables R_s and R_p and identify the curve relating them.
3. Why is the R_s vs. R_p curve not easily identified from the numerical data even with the use of logarithmic graph paper.

Station ⬡ **AVIATION HIGH SCHOOL** Exp.# 75 **APPLIED PHYSICS LABORATORY** Team ○

> "In the course of experience with many generations of students, I have known far more to fail from lack of grit and perserverence than from want of what is commonly called cleverness."
> J. J. Thomson

PROBLEM: To experimentally investigate and apply Lenz's Law to self and mutual induction, and transformer action.

APPARATUS:

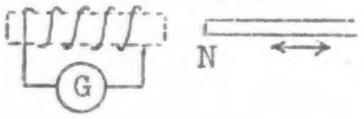
- 200ma-250μa meter
- Large coil & accessories
- Neon lamp and base
- SPST switch
- DPDT switch
- Clip leads
- 10.5h choke
- VTVM
- D battery
- Rheostat
- Magnet

REFERENCES:

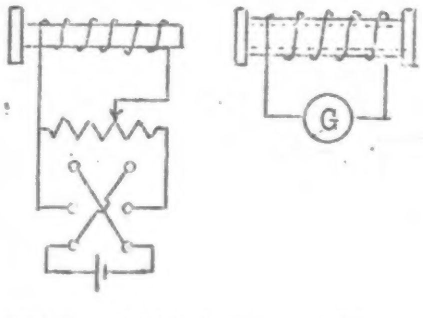
1. Holton, Found. of Mod. Physical Science, pp. 524-30
2. Van Valkenburgh, Basic Elect., pp. 3-43, pp. 3-57

GATHERING THE DATA:

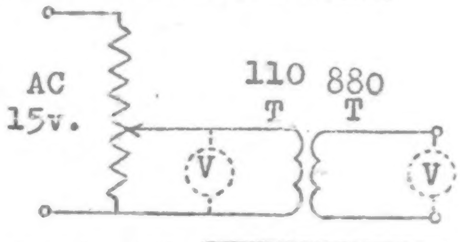
1. Wire circuit as shown & observe effect on galvanometer of:
    a) speed with which magnet moves.
    b) direction of magnet motion.
    c) polarity of magnet.



2. Wire circuit as shown:
    a) close switch & note effect on current in adjacent coil as rate of increasing and decreasing voltage varies.
    b) increase coupling & note effect on I.
    c) gradually insert iron core & note effect on induced current.
    d) flick switch, gradually increase voltage.



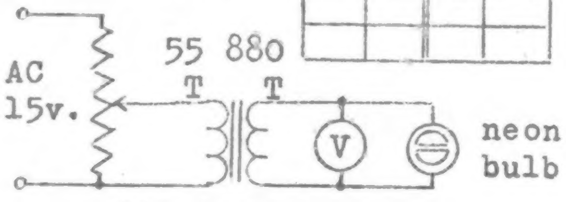
3. Wire circuit as shown & apply integral 5 or 6v. across 110 turn coil:
    a) place 880 turn coil in various positions with respect to 110 turn coil, measure volts.
    b) note effect on voltage of the following:
        -straight iron core in both coils.
        -U iron core through both coils.
        -closed iron core linking both coils.

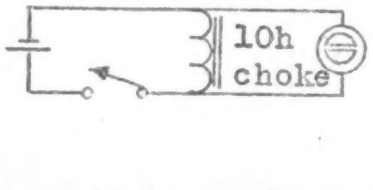


4. a) Using complete transformer, with 5 or 6v. across the 55 turn coil, measure the secondary voltages of 110, 440, and 880 turn coils.
    b) Repeat using 110 turn coil as primary.

T_p	V_p	T_s	V_s

5. a) Set up complete transformer as shown and determine the voltage necessary to brighten the neon bulb.
    b) Wire battery circuit as shown. Open and close switch noting effect.





6. Connect large coil with iron core to 110v.AC (keep switch open).
    (copper a) close switch | c) insert 20 drops | d) (water)

PROBLEM: To experimentally investigate and apply Lenz's Law to self and mutual induction, and transformer action.

APPARATUS:

200ma-250μa meter	10.5h choke
Large coil & accessories	VTVM
Neon lamp and base	D battery
SPST switch	Rheostat
DPDT switch	Magnet
Clip leads	

REFERENCES:

1. Holton, Found. of Mod. Physical Science, pp. 524-30
2. Van Valkenburgh, Basic Elect., pp. 3-43 pp. 3-57

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1. Wire circuit as shown & observe effect on galvanometer of:
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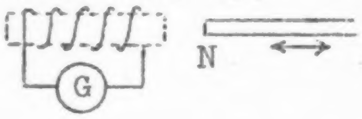
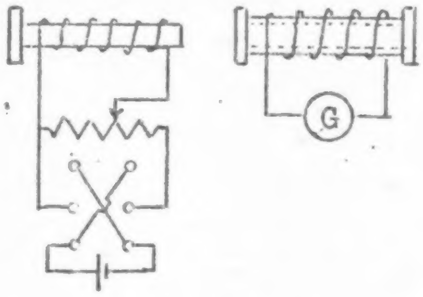


2. Wire circuit as shown:
   a) close switch & note effect on current in adjacent coil as rate of increasing and decreasing voltage varies.
   b) increase coupling & note effect on I.
   c) gradually insert iron core & note effect on induced current.
   d) flick switch, gradually increase voltage.



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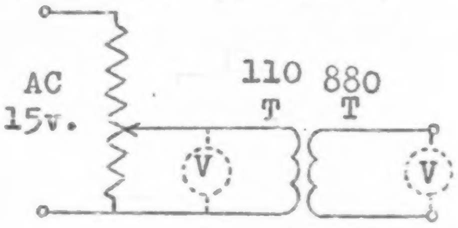
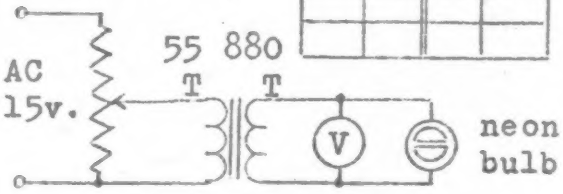
      -straight iron core in both coils.
      -U iron core through both coils.
      -closed iron core linking both coils.

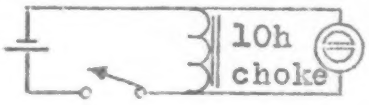


4. a) Using complete transformer, with 5 or 6v. across the 55 turn coil, measure the secondary voltages of 110, 440, and 880 turn coils.
   b) Repeat using 110 turn coil as primary.

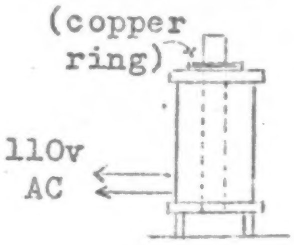
T_p	V_p	T_s	V_s

5. a) Set up complete transformer as shown and determine the voltage necessary to brighten the neon bulb.
   b) Wire battery circuit as shown. Open and close switch noting effect.





6. Connect large coil with iron core to 110v.AC (keep switch open).

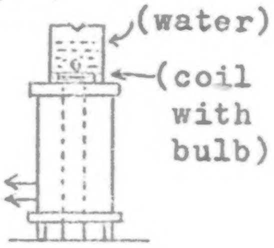


a) close switch & note effect on copper ring.

b) repeat for slotted copper ring.

c) insert 20 drops of water into copper "boiler" securely fastened to top of coil. Close switch and observe.

d)



SUMMATION:

1. Generalize findings of step #1.
2. What causes generated electricity in step #2 -- why is it only momentary? -- why does it reverse direction?
3. What factors determine transformers secondary voltage?
4. Develop an equation for relating transformer primary & secondary voltages.
5. Explain how the 1½v. battery brightens the neon bulb. Why only as the switch opens?
6. Explain the observed phenomena in steps #6a, b, and c.

Station Exp.# 76 Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "A textbook must be exceptionally bad if it is not more intelligible than the majority of notes made by students... the proper function of lectures is not to give a student all the information he needs, but to rouse his enthusiasm so that he will gather knowledge himself, perhaps under difficulty."
>
> J. J. Thomson

PROBLEM: To experimentally test the inverse square law for magnets.

APPARATUS:

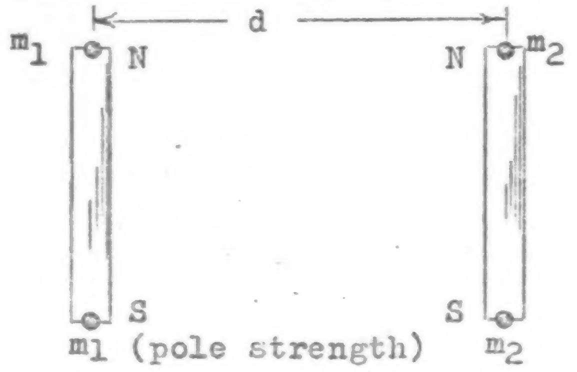
Ground bar magnets
Glass surface board
Spring balance
Triple beam balance
Meter stick
Square
mm scale

REFERENCES:

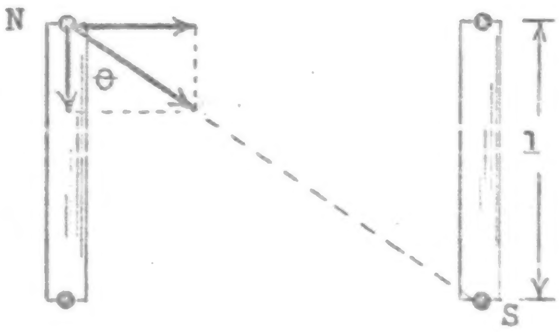
1. White, Modern College Physics, pp. 427-8
2. Stollberg & Hill, Physics, p. 373

GATHERING THE DATA:

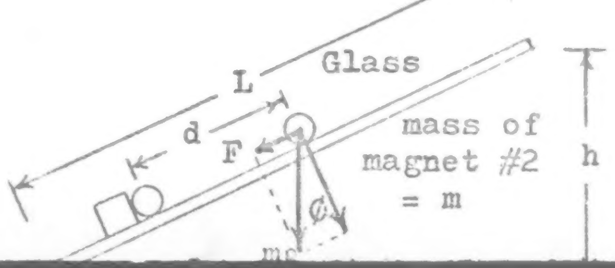
1. a) Consider two bar magnets with poles concentrated at centers of their end faces.
   Applying inverse square law:
   b) North poles repel with force = $\frac{m_1 m_2}{d^2}$
   c) South poles repel with force = $\frac{m_1 m_2}{d^2}$
   d) Total repulsive force = $\frac{2m_1 m_2}{d^2}$



2. a) But since poles always come in pairs, the north and south poles attract.
   Applying inverse square law:
   b) Each pair of opposite poles attracts with force = $\frac{m_1 m_2}{d^2 + l^2}$ (Explain)
   c) But resolving this force into components, the component of the attractive force opposing the repulsive force of step #1 is:
   $$\frac{m_1 m_2}{d^2 + l^2} \sin\theta = \frac{m_1 m_2 d}{(d^2+l^2)^{3/2}}$$ (Explain)
   d) Total attractive force = $\frac{2m_1 m_2 d}{(d^2+l^2)^{3/2}}$
   e) Net repulsive force = $\frac{2m_1 m_2}{d^2} - \frac{2m_1 m_2 d}{(d^2+l^2)^{3/2}} = 2m_1 m_2 \left[\frac{1}{d^2} - \frac{d}{(d^2+l^2)^{3/2}}\right]$



3. Measure net repulsive force:
   a) Set incline at small, approx. 1° angle (make h an integral number of cm)
   b) Bring magnet #2 in contact with magnet #1 & then release--magnet will oscillate back & forth.
   c) Measure distance d as follows:



himself, perhaps under difficulty."

J. J. Thomson

PROBLEM: To experimentally test the inverse square law for magnets.

APPARATUS:

Ground bar magnets
Glass surface board
Spring balance
Triple beam balance
Meter stick
Square
mm scale

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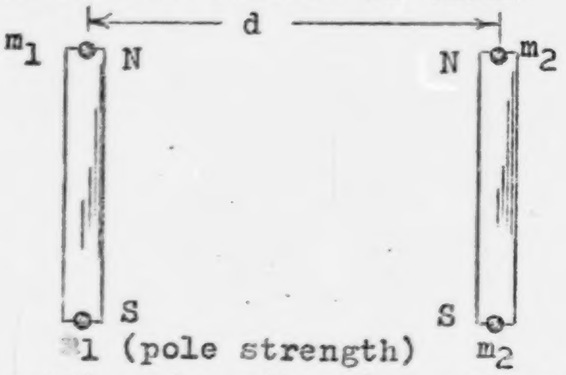
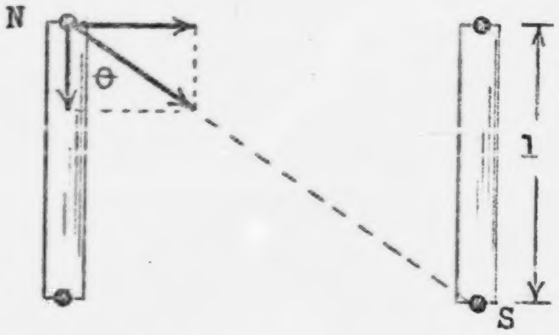
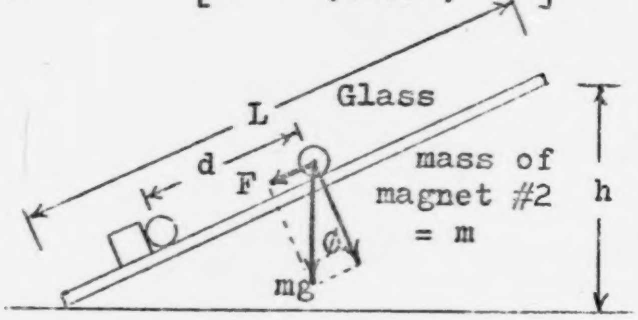
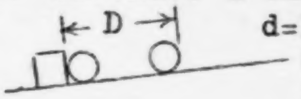


2. a) But since poles always come in pairs, the north and south poles attract.
   Applying inverse square law:
   b) Each pair of opposite poles attracts with force = $\frac{m_1m_2}{d^2+l^2}$ (Explain)
   c) But resolving this force into components, the component of the attractive force opposing the repulsive force of step #1 is:
   $\frac{m_1m_2 \quad \sin\theta}{d^2+l^2} = \frac{m_1m_2d}{(d^2+l^2)^{3/2}}$ (Explain)
   d) Total attractive force = $\frac{2m_1m_2d}{(d^2+l^2)^{3/2}}$
   e) Net repulsive force = $\frac{2m_1m_2}{d^2} - \frac{2m_1m_2d}{(d^2+l^2)^{3/2}} = 2m_1m_2\left[\frac{1}{d^2} - \frac{d}{(d^2+l^2)^{3/2}}\right]$



3. Measure net repulsive force:
   a) Set incline at small, approx. 1° angle (make h an integral number of cm)
   b) Bring magnet #2 in contact with magnet #1 & then release--magnet will oscillate back & forth.
   c) Measure distance d as follows:





d=D-dia.
(use average of several trials)

   d) Ignoring friction: $2m_1m_2\left[\frac{1}{d^2} - \frac{d}{(d^2+l^2)^{3/2}}\right] = mg\frac{h}{L} \rightarrow \left[\frac{1}{d^2} - \frac{d}{(d^2+l^2)^{3/2}}\right] \propto h$ (Explain)

4. Repeat step #3, measuring d for larger h values.
5. Using experimental results, plot $\left[\frac{1}{d^2} - \frac{d}{(d^2+l^2)^{3/2}}\right]$ vs. h

SUMMATION:

1. Do experimental results justify inverse square law?
2. When does assumption that poles are concentrated at points become increasingly untenable?
3. Comment on the statement "...the concept of a pole should be employed but it should be kept constantly in mind that it is an unreality."
4. Devise and implement a test which will include the effects of friction in its results.

Station Exp.# Team

AVIATION HIGH SCHOOL 77 APPLIED PHYSICS LABORATORY

"It is the machines that make life complicated....."

Carl Becker

"'The fault, dear Brutus, is not in our machines, but in ourselves...' Or, to quote that eminent social philosopher of our own day, Pogo, 'we have met the enemy on the field of battle and they are us.'"

Jesse H. Shera

PROBLEM: To measure voltages and frequencies with an oscilloscope.

APPARATUS:

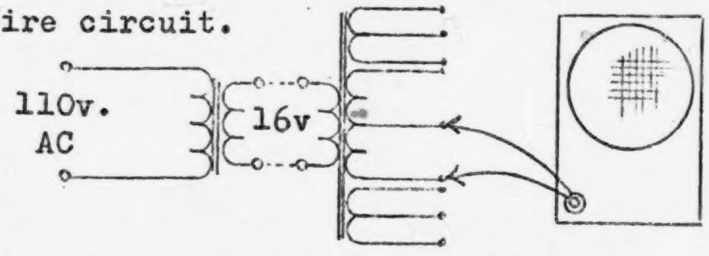
Oscilloscope
Mult. socket base
UTC power transformer
Tuning fork & hammer
Transformer
Clip leads
Scope leads
Microphone

REFERENCES:

1. Turner, Basic Electricity, pp. 378-83
2. Timbie, Basic Electricity for Communications, pp. 294-7

GATHERING THE DATA:

1. a) Turn VERTICAL VERNIER and HORIZONTAL GAIN completely c'clockwise. Set VERTICAL RANGE on 1v. AC.
   b) Connect oscilloscope to 110v. AC, turn INTENSITY on (but at minimum setting), and allow oscilloscope to warm up. Check INDICATOR LIGHT.
   c) Turn INTENSITY clockwise until dot is visible.
      Caution: If dot too bright, oscilloscope may be permanently damaged.
   d) Adjust FOCUS for clearly defined dot.
   e) Manipulate position of dot with VERTICAL CENTERING and HORIZONTAL CENTERING.
   f) Provide manual horizontal sweep by pulling dot across screen with HORIZONTAL CENTERING.
   g) Replace manual horizontal sweep with automatic sweep by turning SWEEP to 15 and adjusting HORIZONTAL GAIN for a 2" or 3" sweep. If necessary, center sweep line using VERTICAL CENTERING and HORIZONTAL CENTERING. Set SYNC for line sync.
   h) Connect probe to VERTICAL INPUT and apply 1 volt peak-to-peak voltage by connecting vertical input probe to 1v.PP and GROUND terminals.
   i) Adjust VERTICAL VERNIER for exactly 1" deflection on graph screen. Adjust SWEEP VERNIER for clearly defined and motionless wave form. Adjust SYNC ADJ. to minimum setting required to lock pattern in stationary position.
      AC VOLTAGE RANGE should be on setting 1 for all of above adjustments.
   j) Remove probe from 1v.PP and GROUND terminals.
2. a) Wire circuit.



Terminals	P-P volts	RMS volts

   b) Check output voltages of the UTC transformer.
      --use appropriate AC voltage range.
         P-P volts = vertical deflection" x AC voltage range.
         RMS volts = (P-P volts) x 0.354
      --list results in table.
      Note: if the vertical vernier setting of step #1i is disturbed, it must be recalibrated.

have met the enemy on the field of battle and they are us.'"

Jesse H. Shera

PROBLEM: To measure voltages and frequencies with an oscilloscope.

APPARATUS:

Oscilloscope	Transformer
Mult. socket base	Clip leads
UTC power transformer	Scope leads
Tuning fork & hammer	Microphone

REFERENCES:

1. Turner, Basic Electricity, pp. 378-83
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   AC VOLTAGE RANGE should be on setting 1 for all of above adjustments.
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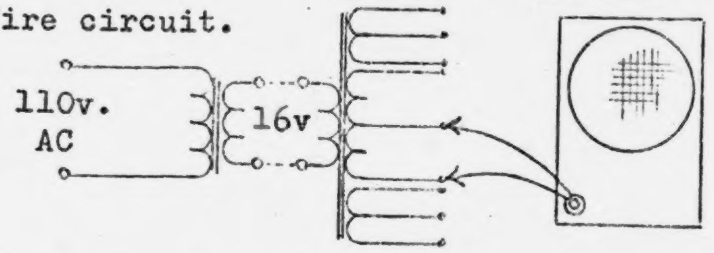
2. a) Wire circuit.



Terminals	P-P volts	RMS volts

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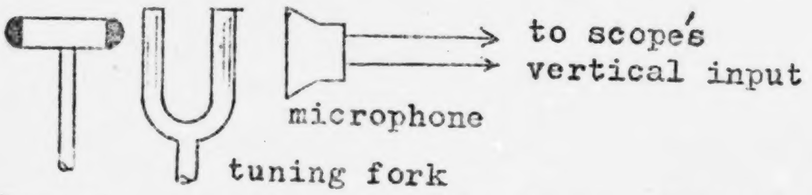
   P-P volts = vertical deflection" x AC voltage range.
   RMS volts = (P-P volts) x 0.354
   --list results in table.
   Note: if the vertical vernier setting of step #1i is disturbed, it must be recalibrated.

3. a) Set up apparatus as shown:



   b) Strike tuning fork A, held close to microphone, & adjust AC vertical range, vertical vernier, sweep, sweep vernier, horizontal gain, & sync for a clearly defined & motionless integral number of cycles.
   c) Without changing any settings, repeat for tuning forks B and C.
   --observe number of cycles for each.
   --vertical amplitudes can be controlled by proximity of tuning forks to the microphone.
   d) Determine the relative frequencies of the tuning forks.

SUMMATION:

1. Examine oscilloscope schematic & explain how 1v.pp is obtained.
2. Explain equations of step #2b.
3. Devise method for determining actual freq. of the tuning forks.

Station 201 Exp.# 78 Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

"...mere dry lectures...without the art of experimentation do not please me; for, after all, all scientific advances must start from experimentation."

Hans Christian Oersted

"We are generally the better persuaded by the reasons we discover ourselves than those given to us by others."

Blaise Pascal

PROBLEM: To determine the charges carried by copper and hydrogen ions in solution.

APPARATUS:

Wire & leads
Anode & cathode
500ml flask
500ml grad. cyl.
Glass & rubber tubing
Safety bottle & stopper
2 iron stands & clamps
Glass tray & 5% H_2SO_4
Stop watch
Vacuum pump
Pinch clamp
Squeeze bottle
Rheostat
Balance
Ammeter
SPST switch

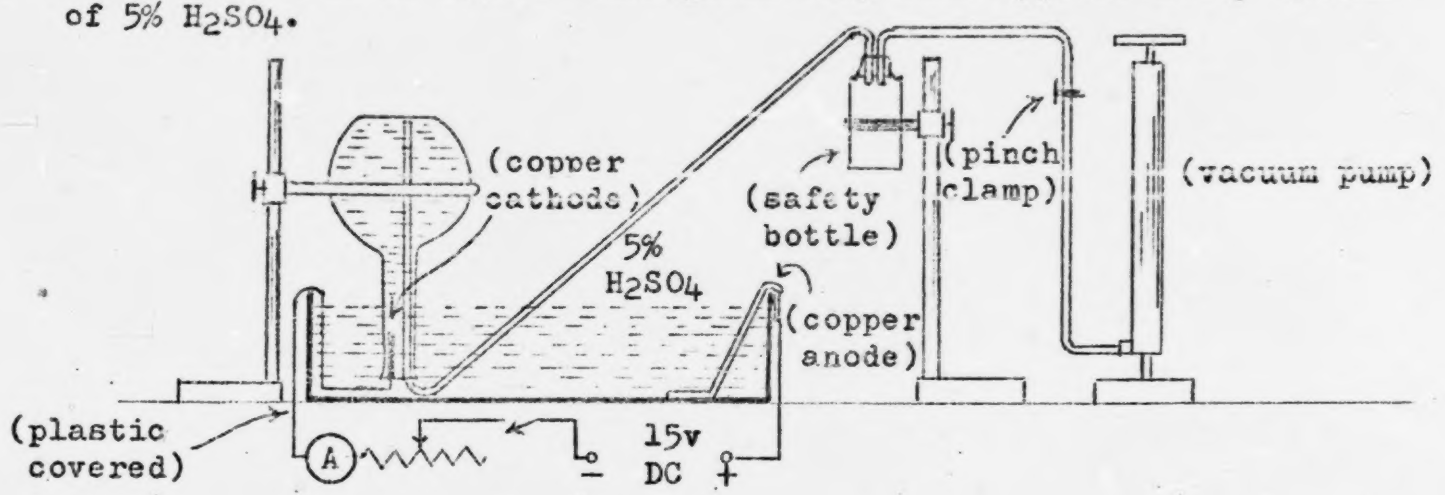
REFERENCES:

1. PSSC, Physics, pp. 514-16

GATHERING THE DATA: WEAR SAFETY GOGGLES DURING EXPERIMENT

1. a) Clean anode and cathode with sand paper.
   b) Measure mass of copper anode and of copper cathode.
   c) Attach clip leads to anode and bend as shown.
   d) Wrap copper wire around cathode and pinch with pliers for good electrical connection. Wire leaving mouth of 500ml flask must be plastic covered.

2. Set up apparatus as shown--fill glass tray with approximately 1500ml of 5% H_2SO_4.



3. Using vacuum pump, fill flask with H_2SO_4 solution and seal tubing with pinch clamp.

4. Adjust rheostat for approximate but constant 5 amps, start, and time.

5. Continue current and time until liquid level in flask is at that of liquid in tray. Note level on flask.

6. Remove copper anode, rinse, carefully dry, and check its mass--repeat for copper cathode.

SUMMATION:

1. Using ammeter reading and time measured, calculate the charge passing through the solution.

2. Determine the number of moles of copper ions formed by dividing the

"We are generally the better persuaded by the reasons we discover ourselves than those given to us by others." Blaise Pascal

PROBLEM: To determine the charges carried by copper and hydrogen ions in solution.

APPARATUS:

- Wire & leads
- Anode & cathode
- 500ml flask
- 500ml grad. cyl.
- Glass & rubber tubing
- Safety bottle & stopper
- 2 iron stands & clamps
- Glass tray & 5% H_2SO_4
- Stop watch
- Vacuum pump
- Pinch clamp
- Squeeze bottle
- Rheostat
- Balance
- Ammeter
- SPST switch

REFERENCES:

1. PSSC, Physics, pp. 514-16

GATHERING THE DATA: WEAR SAFETY GOGGLES DURING EXPERIMENT

1. a) Clean anode and cathode with sand paper.
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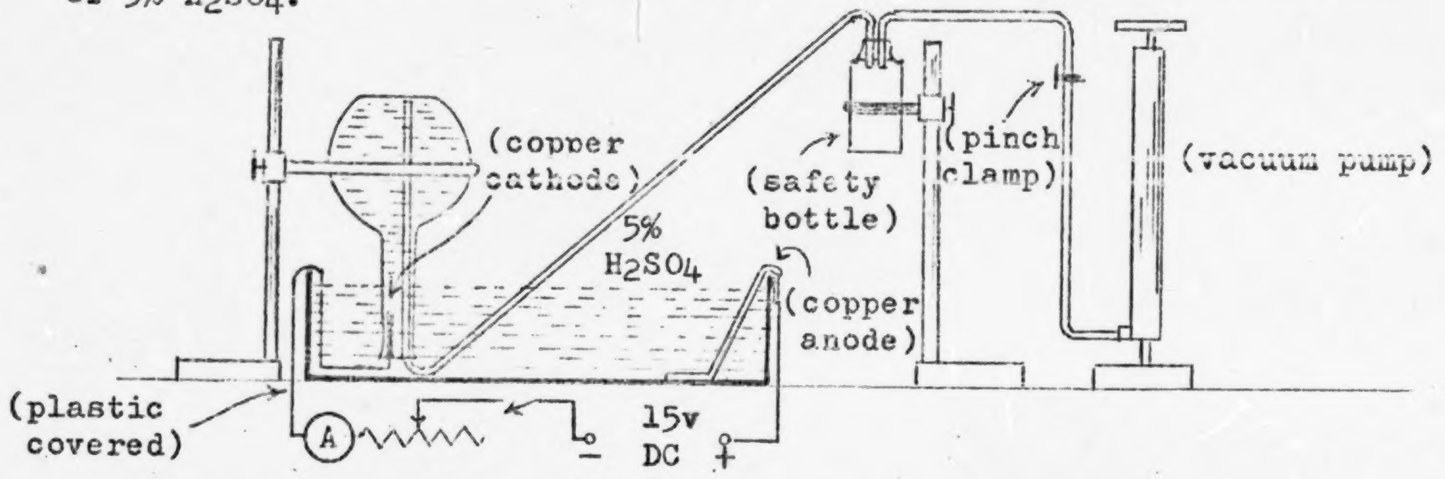

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4. Adjust rheostat for approximate but constant 5 amps, start, and time.
5. Continue current and time until liquid level in flask is at that of liquid in tray. Note level on flask.
6. Remove copper anode, rinse, carefully dry, and check its mass--repeat for copper cathode.

SUMMATION:

1. Using ammeter reading and time measured, calculate the charge passing through the solution.
2. Determine the number of moles of copper ions formed by dividing the grams lost by the anode by the atomic mass of copper. Justify.
3. Determine the number of copper ions using Avogadro's number. (Assume all of the copper ions are identically charged.)
4. Determine the number of elementary charges per copper ion.
5. Determine the charge per hydrogen molecule. Per hydrogen atom.
6. Does cathode mass increase? If it does, what effect would this have on the charge/hydrogen atom?

Station ⬡ | AVIATION HIGH SCHOOL | Exp.# 79 | APPLIED PHYSICS LABORATORY | Team ○

> "...we have come to regard action at a distance as a process impossible without the intervention of some intermediary medium. If, for instance, a magnet attracts a piece of iron...we are constrained to imagine--after the manner of Faraday--that the magnet always calls into being something physically real in the space around it, that something being what we call a 'magnetic field'."
>
> Albert Einstein

PROBLEM: To use the earth's magnetic field to determine factors in magnetic field strength.

APPARATUS:

DPDT switch
Graph paper
Coil frame
Compass & board
Long wire & support
Ammeter
Rheostat
Clamps
Clip leads

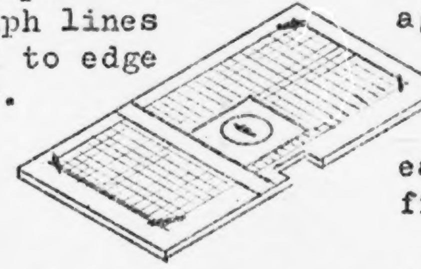
REFERENCES:

1. PSSC, Physics, pp. 560-1
2. Semat, Fund. of Physics, pp. 435-37

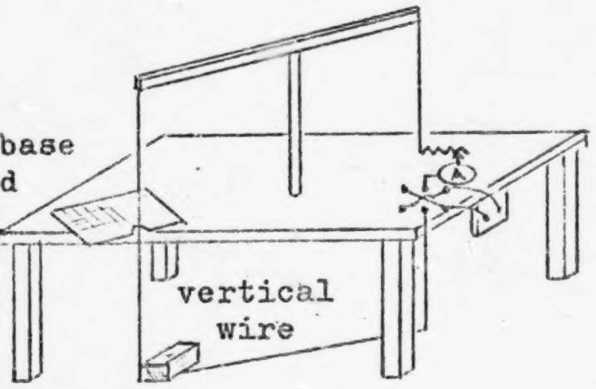
GATHERING THE DATA:

1. Set up apparatus as shown:

a) tape paper to board with graph lines parallel to edge of guide.



b) place compass base against guide and shift board until length of paper ⊥ to earth's magnetic field.

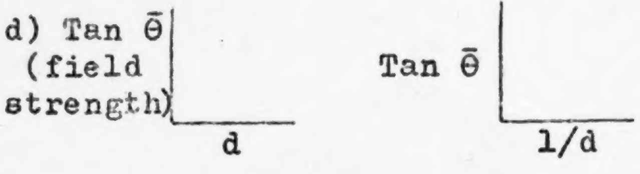


2. With compass base against guide, move compass away from wire and verify that compass is unaffected. Nearby iron distorts earth's field.

3. a) With compass base against guide and compass close to wire, adjust rheostat for 5a through wire and note angular deflection of compass θ_1. Open and close switch several times in making reading.
   b) Reverse current and note angular deflection of compass θ_2.
   c) Repeat a & b as compass is moved in ½" steps from the wire. Record data in table.

d	amps	θ_1	θ_2	$\bar{\theta}$	tan $\bar{\theta}$

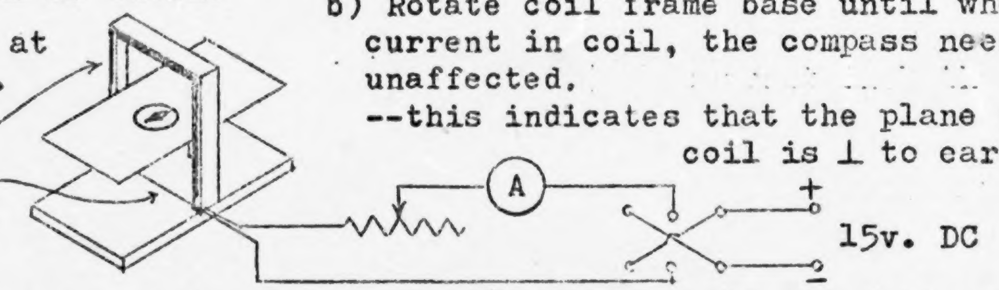
d)



4. Set up apparatus as shown:

a) Place compass at center of board.

(wire loop)



b) Rotate coil frame base until when large current in coil, the compass needle is unaffected.
--this indicates that the plane of the coil is ⊥ to earth's field.

c) Press straight edge against edge of coil frame, hold straight edge firmly while rotating coil frame 90° --now coil's plane ∥ to earth's magnetic field.

5. Raise current in small increments--recording the angular deflection of the compass, ϕ_1 and the angular deflection for reversed current, ϕ_2.

Amps	ϕ_1	ϕ_2	ϕ	tan ϕ

6. Plot graph.

> being something physically real in the space around it, that
> something being what we call a 'magnetic field'."
> Albert Einstein

PROBLEM: To use the earth's magnetic field to determine factors in magnetic field strength.

APPARATUS:

DPDT switch	Ammeter
Graph paper	Rheostat
Coil frame	Clamps
Compass & board	Clip leads
Long wire & support	

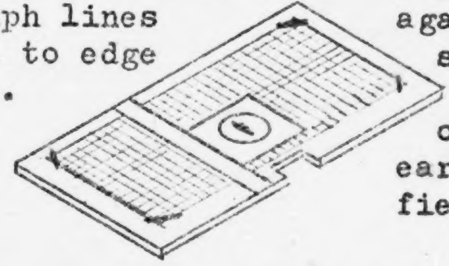
REFERENCES:

1. PSSC, *Physics*, pp. 560-1
2. Semat, *Fund. of Physics*, pp. 435-37

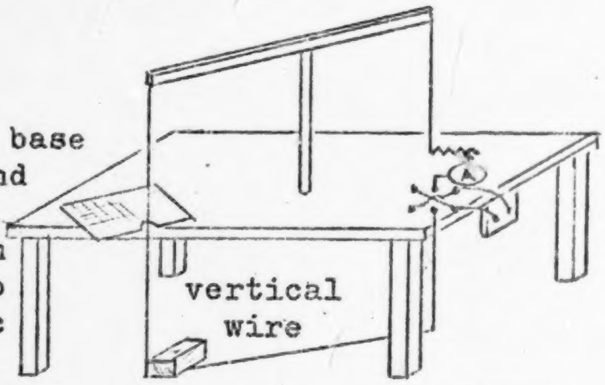
GATHERING THE DATA:

1. Set up apparatus as shown:

a) tape paper to board with graph lines parallel to edge of guide.



b) place compass base against guide and shift board until length of paper ⊥ to earth's magnetic field.

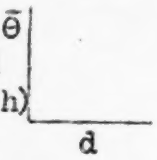


2. With compass base against guide, move compass away from wire and verify that compass is unaffected. Nearby iron distorts earth's field.

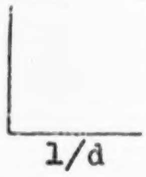
3. a) With compass base against guide and compass close to wire, adjust rheostat for 5a through wire and note angular deflection of compass θ_1. Open and close switch several times in making reading.
   b) Reverse current and note angular deflection of compass θ_2.
   c) Repeat a & b as compass is moved in ½" steps from the wire. Record data in table.

d	amps	θ_1	θ_2	$\bar{\theta}$	tan $\bar{\theta}$

   d) Tan $\bar{\theta}$ (field strength)



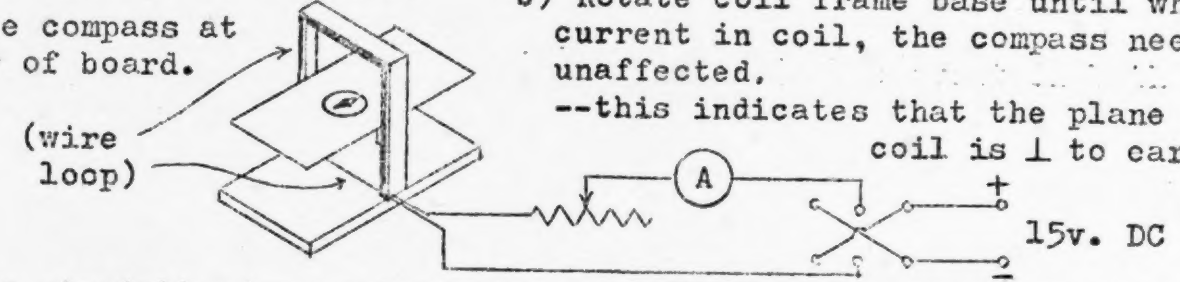
Tan $\bar{\theta}$



4. Set up apparatus as shown:

a) Place compass at center of board.

b) Rotate coil frame base until when large current in coil, the compass needle is unaffected.
--this indicates that the plane of the coil is ⊥ to earth's field.



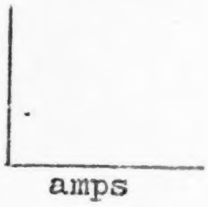
c) Press straight edge against edge of coil frame, hold straight edge firmly while rotating coil frame 90° --now coil's plane ∥ to earth's magnetic field.

5. Raise current in small increments--recording the angular deflection of the compass, $\emptyset_1$ and the angular deflection for reversed current, $\emptyset_2$.

Amps	$\emptyset_1$	$\emptyset_2$	$\bar{\emptyset}$	tan $\bar{\emptyset}$

6. Plot graph.

Tan Ø (field strength)



7. a) Set current at 0.1 amps and note compass deflection.
   b) Repeat a using 2, 3, etc. loops of wire.

8. Send large current through two coils wound in opposite directions and note compass deflection.

SUMMATION:

1. What are the factors in magnetic field strength? Explain in detail.
2. Justify: tangent of deflection angle ∝ field strength.

Station ⬡ **AVIATION HIGH SCHOOL** Exp. # 80 **APPLIED PHYSICS LABORATORY** Team ○

> "Dr. James R. Killian (former president of M. I. T.) tells the story of a faculty meeting that was deciding the fate of those students who were failing in one or more of their courses. When it was announced that a student named Cicero was failing in Latin, everyone laughed. A little later when it was announced that a student named Gauss was failing in mathematics, only the scientists laughed."
>
> D. Wolfe

PROBLEM: To measure magnetic induction in $\frac{\text{newtons}}{\text{ampere-meter}}$ and gausses.

APPARATUS:

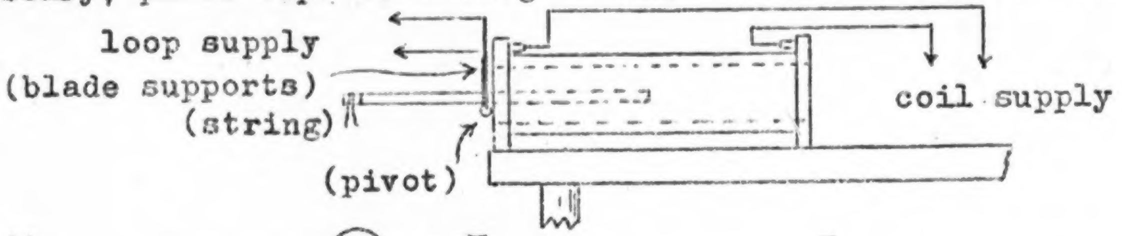
2 ammeters
Air core solenoid
Triple beam balance
Current balance & contacts
Clip leads
Meter stick
2 rheostats
String
2 SPST switches

REFERENCES:

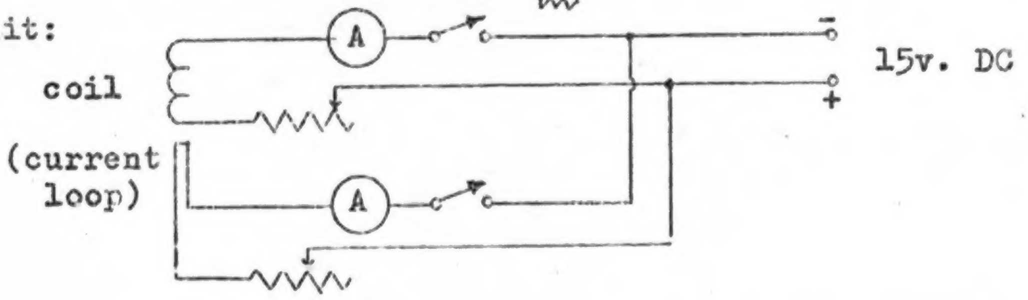
1. PSSC, *Physics*, pp. 563-566

GATHERING THE DATA:

1. a) Place air core solenoid at edge of lab. table and mount current loop blade on supports such that it is centered in the solenoid.
   b) If necessary, place tape or string on end of blade to level it.



2. Wire circuit:



3. a) Send 4 amps through solenoid and approximately 1 amp through current loop.
   b) Roughly balance current loop by adding short string to extreme end of the current loop and then carefully balance the loop by adjusting the current through it.
   c) Determine force F (in newtons): weigh a long carefully measured length of the string and then use proportions to determine force F exerted by the short string used for leveling the current loop.
4. Determine magnetic induction B at center of solenoid:

   $F = BIL \quad B = \frac{F}{IL}$

   I = loop current
   L = length in meters of end of current loop
5. Repeat steps #3 and #4 with 2 amps and then 3 amps through current loop.
6. Repeat steps #3, 4 and 5 but with 5 amps through solenoid.

SUMMATION:

1. In the MKS system, B units are in newtons or webers. Explain.

student named Gauss was failing in mathematics, only the scientists laughed."

D. Wolfe

PROBLEM: To measure magnetic induction in $\frac{\text{newtons}}{\text{ampere-meter}}$ and gausses.

APPARATUS:

2 ammeters
Clip leads
Air core solenoid
Meter stick
Triple beam balance
2 rheostats
Current balance & contacts
String
2 SPST switches

REFERENCES:

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GATHERING THE DATA:

1. a) Place air core solenoid at edge of lab. table and mount current loop blade on supports such that it is centered in the solenoid.
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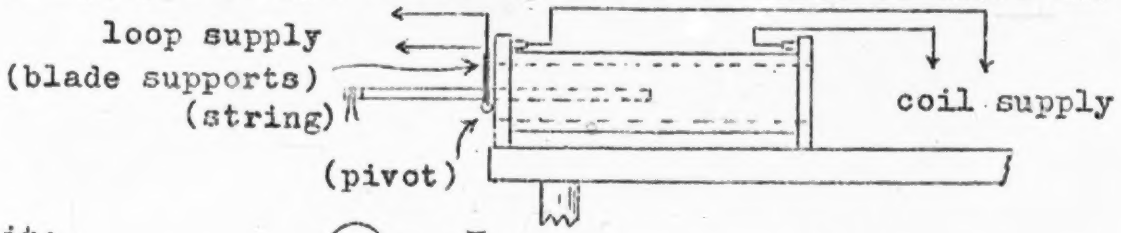

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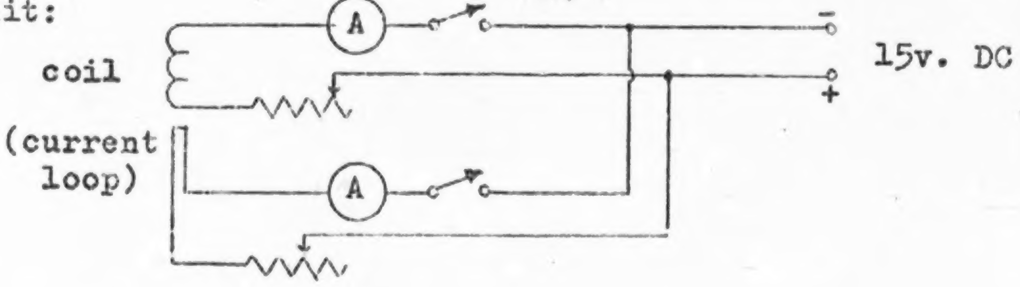

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5. Repeat steps #3 and #4 with 2 amps and then 3 amps through current loop.
6. Repeat steps #3, 4 and 5 but with 5 amps through solenoid.

SUMMATION:

1. In the MKS system, B units are in $\frac{\text{newtons}}{\text{amp. meter}}$ or $\frac{\text{webers}}{\text{meter}^2}$. Explain.
2. In the CGS system, B units are in $\frac{\text{maxwells}}{\text{cm}^2}$ or gausses. Convert the experimentally measured MKS magnetic induction units to CGS units.
3. a) Explain how the current loop can be used to measure the earth's magnetic field.
   b) Explain why it is not practical to use this experiment's current loop to make this measurement.
4. Determine the coil constant B/I for the following experiment.

Station

AVIATION HIGH SCHOOL

Exp.# 81

APPLIED PHYSICS LABORATORY

Team

> "No man ever had genius who did not aim to execute more than he was able."
>
> Humphry Davy
>
> "Ah, but a man's reach should exceed his grasp,
> Or what's a heaven for?"
>
> Robert Browning

PROBLEM: To measure the mass of an electron.

APPARATUS:

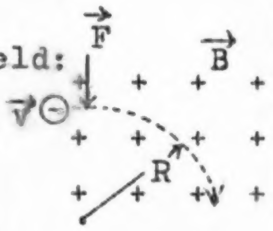
VTVM
Ammeter
Rheostat
6AF6 tube & assembly
Variable high volt. DC supply
Coil
Clip leads
Storage battery
2 SPST switches

REFERENCES

1. PSSC, Lab. Guide, pp. 79-81
2. PSSC, Physics, pp. 552-54, pp. 556-58

THEORY:

1. Electron moving perpendicularly through a uniform magnetic field:



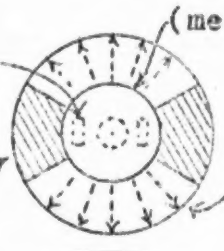
$$\left.\begin{aligned} &F = Bev \\ &\text{\& since force} \perp \text{\& centripetal} \\ &F = \frac{mv^2}{R} \end{aligned}\right] \longrightarrow v = \frac{BeR}{m} \qquad v^2 = \frac{B^2e^2R^2}{m^2}$$

& electron velocity v due to potential difference between cathode and anode:

$$V = \frac{W}{e} \qquad W = \frac{mv^2}{2} = Ve \qquad v^2 = \frac{2Ve}{m}$$

$$\longrightarrow m = \frac{B^2eR^2}{2V}$$

2. 6AF6 tube:

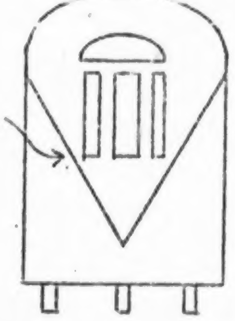


(metal cap)

(deflecting electrodes)

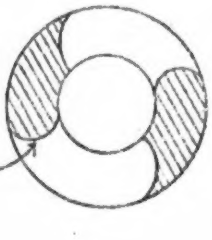
(electrons emerge from under metal cap with constant velocity and move toward anode)

(shadow since no electron strike this portion of anode)



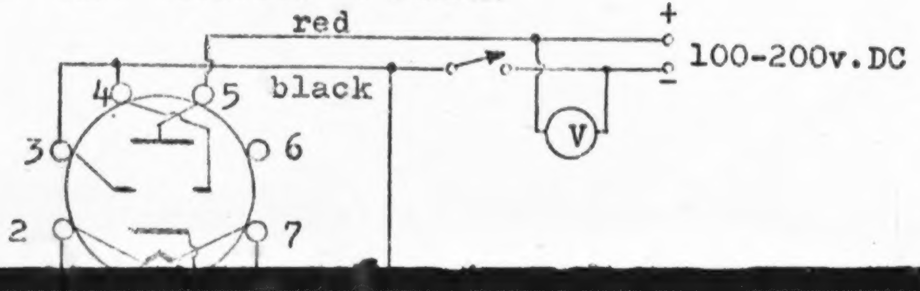
(coated conical anode emits light when struck by electrons)

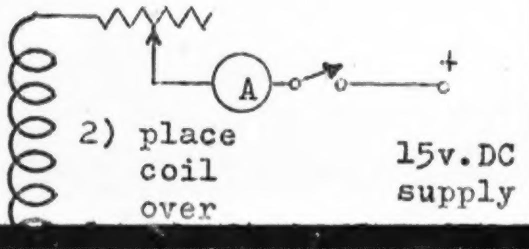
(when magnetic field applied perpendicularly to paths of electrons, the electrons are deflected and a pattern with a measurable radius R emerges)



GATHERING THE DATA:

1. Wire circuits as shown:





2) place coil over

Or what's a heaven for?"

Robert Browning

PROBLEM: To measure the mass of an electron.

APPARATUS:

VTVM
Coil
2 SPST switches
Ammeter
Clip leads
Rheostat
Storage battery
6AF6 tube & assembly
Variable high volt. DC supply

REFERENCES

1. PSSC, *Lab. Guide*, pp. 79-81
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THEORY:

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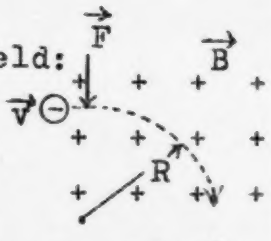


$$F = Bev$$

& since force ⊥ & centripetal

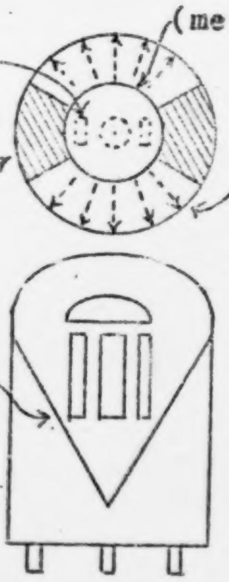
$$F = \frac{mv^2}{R} \longrightarrow v = \frac{BeR}{m} \qquad v^2 = \frac{B^2e^2R^2}{m^2}$$

& electron velocity v due to potential difference between cathode and anode:

$$V = \frac{W}{e} \qquad W = \frac{mv^2}{2} = Ve \qquad v^2 = \frac{2Ve}{m}$$

$$\longrightarrow m = \frac{B^2eR^2}{2V}$$

2. 6AF6 tube:



(metal cap)

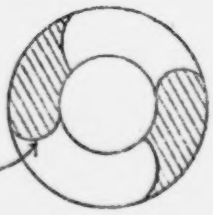
(deflecting electrodes)

(electrons emerge from under metal cap with constant velocity and move toward anode)

(shadow since no electron strike this portion of anode)

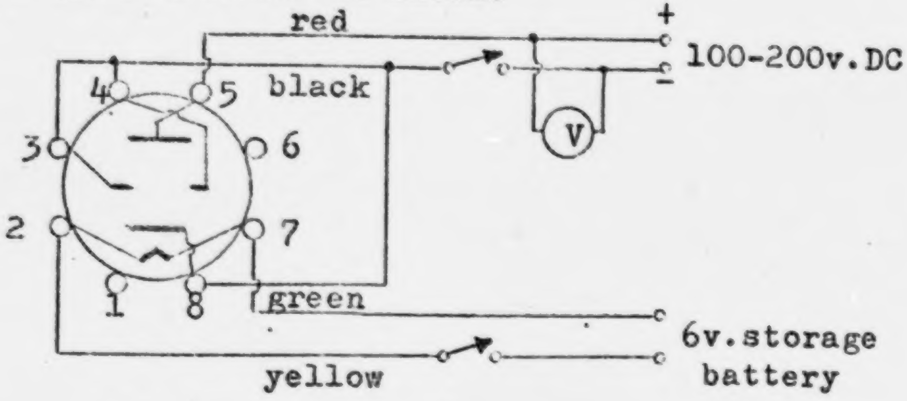
(coated conical anode emits light when struck by electrons)

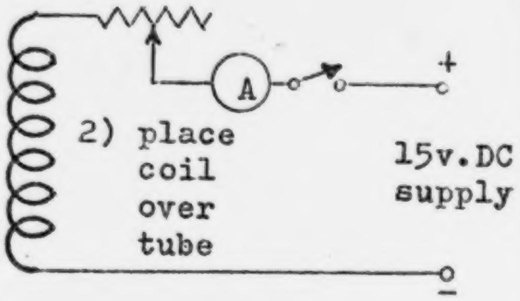
(when magnetic field applied perpendicularly to paths of electrons, the electrons are deflected and a pattern with a measurable radius R emerges)



GATHERING THE DATA:

1. Wire circuits as shown:





2) place coil over tube

3. Set anode voltage to approximately 130v.

4. Adjust current through coil until curvature at edge of shadow equals that of coin whose radius R is easily measured.

5. Repeat steps #3 and #4 for other anode potentials and field currents.

SUMMATION:

Calculate electron mass.

Note: Use coil constant data to determine B.

Station AVIATION HIGH SCHOOL Exp.# 82 APPLIED PHYSICS LABORATORY Team

> "It is not derogatory of a discoverer to say that his discovery arose from an accident for the power to use accidents is the work of one form of scientific genius. Probably all experimenters are presented with about the same number of accidents which, if they had the wit, would have led them to important discoveries."
>
> Norman Campbell
>
> "..in the field of experimentation, accident favors the prepared mind."
>
> Louis Pasteur

PROBLEM: To experimentally analyze the operation of synchro transmitters and receivers.

APPARATUS:

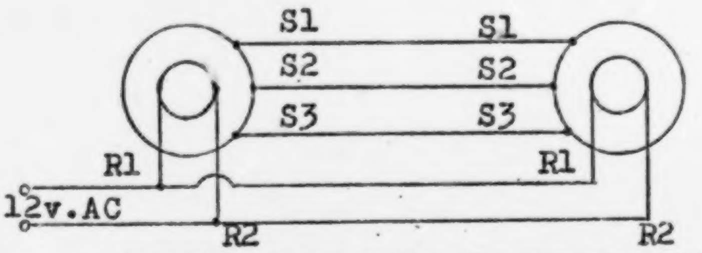
2 synchros	Battery
Clip leads	VTVM

REFERENCES:

1. Philco, Synchros & Servomechanisms, pp. 8-17
   pp. 53-54
2. VanValkenburgh, Basic Electricity, pp.5:108-9

GATHERING THE DATA:

1. a) Connect transmitter and receiver as shown & rotate stator housings until both rotor pointers point in the same direction. Set dials to read zero degrees.
   b) Turn transmitter rotor and note the direction of receiver rotation.

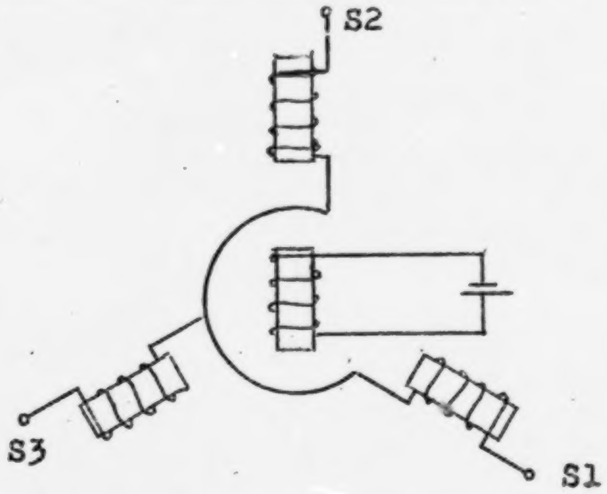


2. Successively rewire synchro system according to table and record:
   a) Position of receiver when transmitter indicates zero degrees.
   b) Receiver rotation when transmitter is rotated in a counter clockwise direction.

Transmitter	S1	S2	S3	R1	R2
Receiver	S1	S3	S2	R1	R2
"	S2	S1	S3	R1	R2
"	S2	S3	S1	R1	R2
"	S3	S1	S2	R1	R2
"	S3	S2	S1	R1	R2

3. Repeat step #2 with rotor lead reversed.
4. Test synchro with D.C.
   a) Apply D.C. to rotor shaft.
   b) Successively apply D.C. to stator coils wired as shown and in each case record the position of the rotor pointer.
   c) Using vectors, determine the direction of the resultant field of the stator coils.

   Note: In each instance one coil receives twice as much current as either of the other coils.



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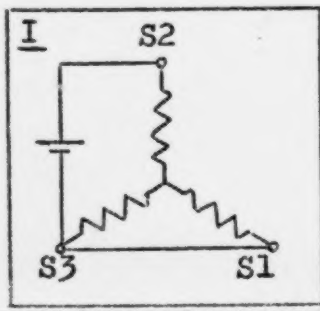

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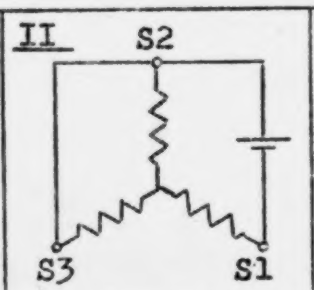

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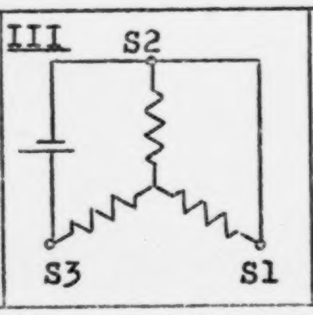

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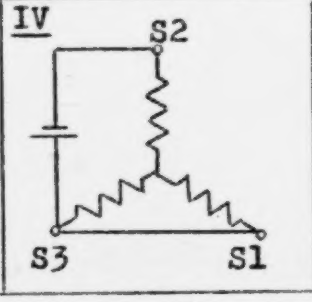

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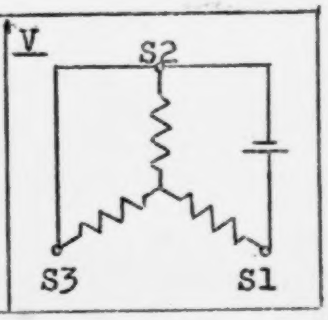


would have led them to important discoveries."

Norman Campbell

"..in the field of experimentation, accident favors the prepared mind."

Louis Pasteur

PROBLEM: To experimentally analyze the operation of synchro transmitters and receivers.

APPARATUS:

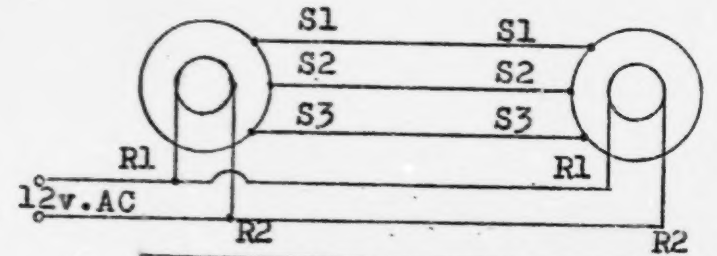
2 synchros	Battery
Clip leads	VTVM

REFERENCES:

1. Philco, Synchros & Servomechanisms, pp. 8-17
pp. 53-54
2. VanValkenburgh, Basic Electricity, pp.5:108-9

GATHERING THE DATA:

1. a) Connect transmitter and receiver as shown & rotate stator housings until both rotor pointers point in the same direction. Set dials to read zero degrees.
   b) Turn transmitter rotor and note the direction of receiver rotation.



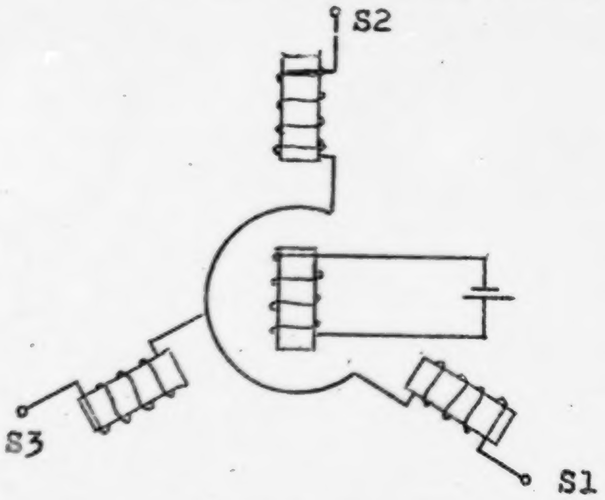
2. Successively rewire synchro system according to table and record:
   a) Position of receiver when transmitter indicates zero degrees.
   b) Receiver rotation when transmitter is rotated in a counter clockwise direction.

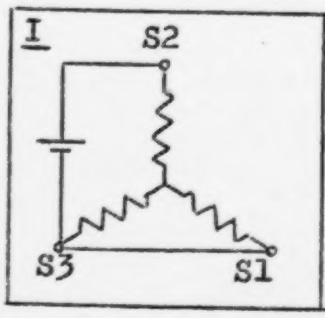
Transmitter	S1	S2	S3	R1	R2
Receiver	S1	S3	S2	R1	R2
"	S2	S1	S3	R1	R2
"	S2	S3	S1	R1	R2
"	S3	S1	S2	R1	R2
"	S3	S2	S1	R1	R2

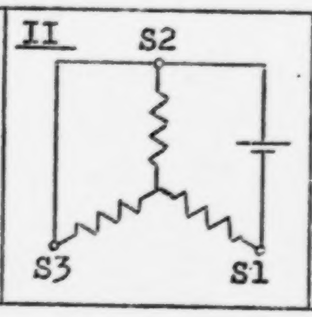
3. Repeat step #2 with rotor lead reversed.

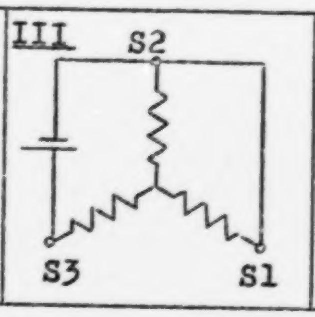
4. Test synchro with D.C.
   a) Apply D.C. to rotor shaft.
   b) Successively apply D.C. to stator coils wired as shown and in each case record the position of the rotor pointer.
   c) Using vectors, determine the direction of the resultant field of the stator coils.

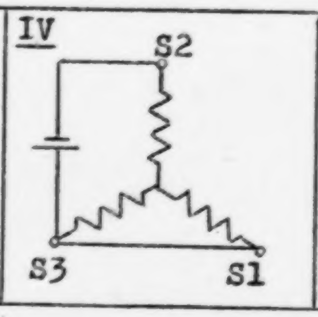
Note: In each instance one coil receives twice as much current as either of the other coils.

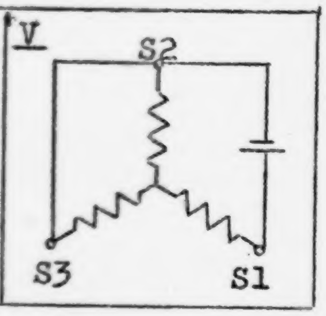












5. Apply 12v. A.C. to transmitter rotor and check corresponding voltages at the stator terminals for the given rotor positions.

Rotor Position	S2-S1	S2-S3	S1-S3
0°			
30°			
330°			

SUMMATION:

Explain how the application of A.C. to the synchro rotors enables the receiver rotor to follow the transmitter rotor.

Station

Exp.# 83

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

Team

> "Success in explaining facts is not necessarily proof of the validity of an hypothesis, for, as Leibnitz puts it...it is possible to infer the truth from false premises."
>
> J. W. Mellor

PROBLEM: To examine the charging of a capacitor and to predict the time required to reach various voltages.

APPARATUS:

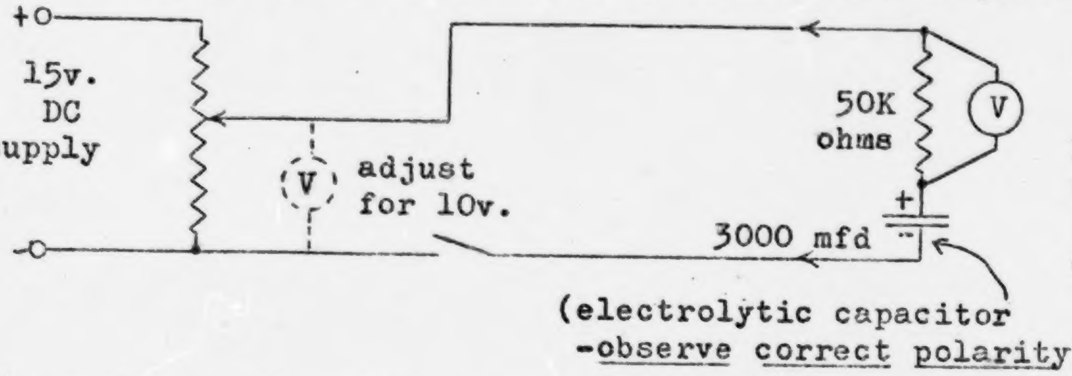
Stop watch	Potentiometer
VTVM	12 clip leads
SPST switch	Graph paper
Resistances	
3000 & 3300 mfd capacitors	

REFERENCES:

1. Timbie, Basic Electricity for Communications, pp. 271-3
2. Philco, Basic Concepts & D.C. Circuits, pp. 217-21
3. Van Valkenburgh, Basic Electricity, p. 3--106

GATHERING THE DATA:

1. Wire circuit as shown and adjust potentiometer output for an accurate 10v.



(electrolytic capacitor -observe correct polarity)

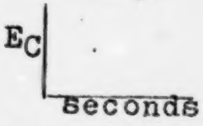
VTVM on 12v. DC scale

Note: VTVM must warm up before it gives stable and accurate readings.

2. a) Simultaneously close switch and start stop watch.
   b) Record elapsed time for every volt (or ½ volt) decrease in the voltage across the 50K ohm resistor. (Record total elapsed time and voltage in table--time for approximately 10-15 minutes)
   c) Open switch and discharge capacitor by shorting + and - .

E_R	Total time	E_C
10v		
9.5v		
etc.		

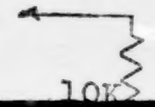
3. Calculate E_C (the voltage across the capacitor) using Kirchhoff's voltage law and insert in table.
4. a) Plot graph: (use entire sheet)



   b) Using Universal time constant curve, and same scale as in a, plot a theoretical curve of charge on the same sheet with empirical curve and compare.
5. a) Using the theoretical and empirical curves, predict the voltages to which the capacitors in the following circuits will charge to in the specified times --record predictions in table:

t(sec)	R(ohms)	C(mfd)	E(theory)	E(exp.)
30	10K	3000		
60	10K	3000		
600	200K	3000		

A.



B.

C.

D.

E.

PROBLEM: To examine the charging of a capacitor and to predict the time required to reach various voltages.

APPARATUS:

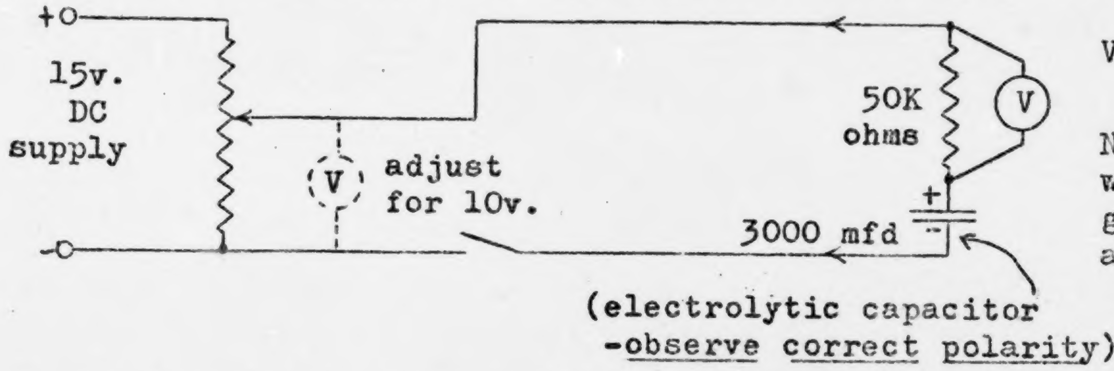
Stop watch	Potentiometer
VTVM	12 clip leads
SPST switch	Graph paper
Resistances	
3000 & 3300 mfd capacitors	

REFERENCES:

1. Timbie, Basic Electricity for Communications, pp. 271-3
2. Philco, Basic Concepts & D.C. Circuits, pp. 217-21
3. Van Valkenburgh, Basic Electricity, p. 3--106

GATHERING THE DATA:

1. Wire circuit as shown and adjust potentiometer output for an accurate 10v.



VTVM on 12v. DC scale

Note: VTVM must warm up before it gives stable and accurate readings.

2. a) Simultaneously close switch and start stop watch.
   b) Record elapsed time for every volt (or ½ volt) decrease in the voltage across the 50K ohm resistor. (Record total elapsed time and voltage in table--time for approximately 10-15 minutes)
   c) Open switch and discharge capacitor by shorting + and - .

E_R	Total time	E_C
10v		
9.5v		
etc.		

3. Calculate E_C (the voltage across the capacitor) using Kirchhoff's voltage law and insert in table.

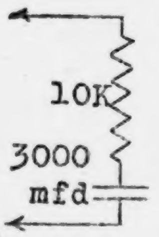
4. a) Plot graph: (use entire sheet)

   b) Using Universal time constant curve, and same scale as in a, plot a theoretical curve of charge on the same sheet with empirical curve and compare.

5. a) Using the theoretical and empirical curves, predict the voltages to which the capacitors in the following circuits will charge to in the specified times --record predictions in table:

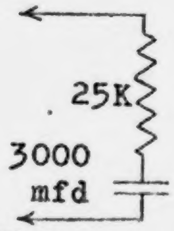
t(sec)	R(ohms)	C(mfd)	E(theory)	E(exp.)
30	10K	3000		
60	10K	3000		
600	200K	3000		

A.



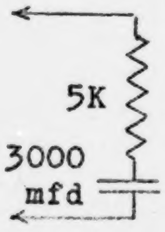
after:
a) 30 sec.
b) 60 sec.

B.



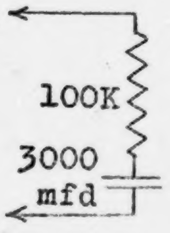
after:
a) 75 sec.
b) 100 sec.

C.



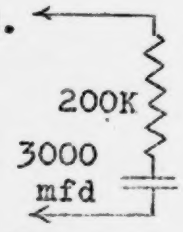
after:
a) 15 sec.
b) 30 sec.

D.



after:
a) 150 sec.
b) 300 sec.

E.



after:
a) 100 sec.
b) 600 sec.

   b) Experimentally check predictions--record results in table. (discharge capacitor after each test)

SUMMATION:

1. Explain in detail why the charging curve for a capacitor takes the form that it does.
2. Generalize the experimental results and apply generalization to other combinations of resistance and capacitance that can be subjected to test. Test!

Station

Exp. #

84

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

Team

> "Biologists have found that... The predominating periodic fluctuations which constitute the chief regulatory mechanism of nature are... relaxation oscillations. An example which exhibits the periodicity of relaxation is the evolution of a population of field mice or other small rodents. Their growth follows the logistic pattern up to a point where they arevery numerous. Then suddenly they are decimated by an epidemic. The survivors slowly recover, begin to multiply, and again the population becomes large, whereupon the same cycle of sudden epidemic decimation and gradual recovery repeats itself at more or less regular intervals."
>
> Betz, Burcham and Ewing

PROBLEM: To design and construct relaxation oscillators satisfying prescribed requirements.

APPARATUS:

- DC power supply VTVM
- Stop watch
- Clip leads
- SPST switch
- Neon bulb and base
- Peg board, resistors, & capacitors

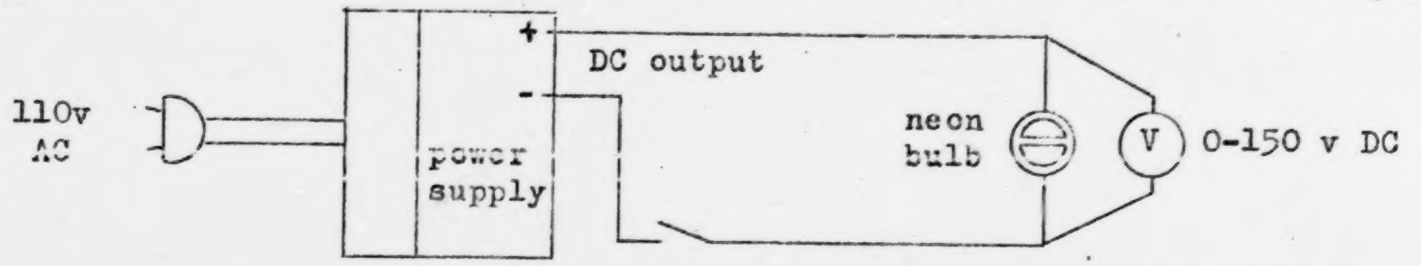
REFERENCES:

1. Philco, Basic Concepts Vol. I pp. 223-4
2. Turner, Basic Electricity pp. 378-83
3. White, Modern College Physics pp. 550-1

GATHERING THE DATA:

Precaution: Do not touch circuit while power supply is on. Turn off when making or changing connections.

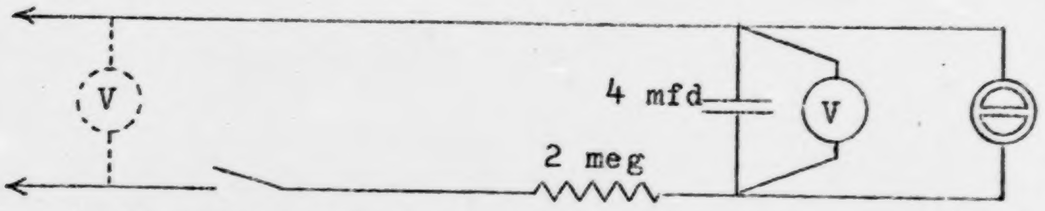
1. Test neon bulb across 110v AC
2. a) Wire circuit as shown with power supply adjusted for minimum voltage.



b) Close switch, slowly increase voltage, and note the voltage when neon bulb first brightens. (do not exceed 100v)--repeat several times to insure consistency.

c) Adjust voltage to brighten bulb, then slowly decrease voltage, and observe voltage at which bulb goes out--repeat several times to insure consistency.

3. a) Wire the following circuit:



b) Adjust power supply to 100v.

c) Close switch and time for T (10 flashes).
-count first flash zero as timing starts.
-check several times for consistency--use mean if necessary.

R	C	T (sec)	Period
2 meg	4 mfd		

> mice or other small rodents. Their growth follows the logistic pattern up to a point where they arevery numerous. Then suddenly they are decimated by an epidemic. The survivors slowly recover, begin to multiply, and again the population becomes large, whereupon the same cycle of sudden epidemic decimation and gradual recovery repeats itself at more or less regular intervals."
>
> Betz, Burcham and Ewing

PROBLEM: To design and construct relaxation oscillators satisfying prescribed requirements.

APPARATUS:

DC power supply
VTVM
Stop watch
Clip leads
SPST switch
Neon bulb and base
Peg board, resistors, & capacitors

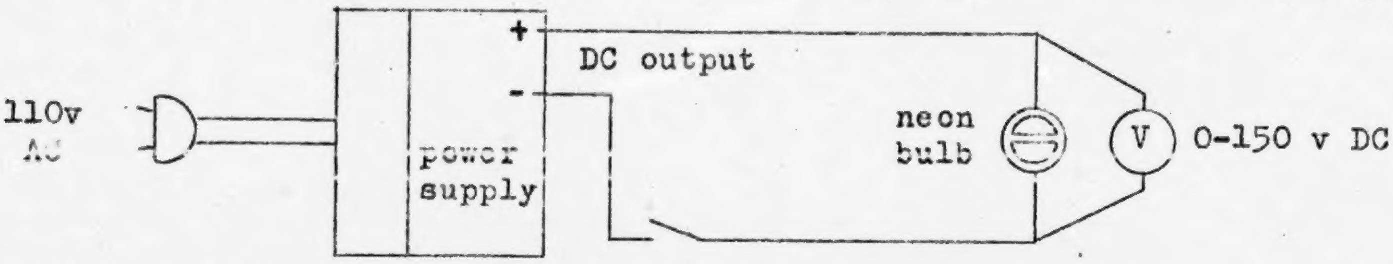
REFERENCES:

1. Philco, Basic Concepts Vol. I pp. 223-4
2. Turner, Basic Electricity pp. 378-83
3. White, Modern College Physics pp. 550-1

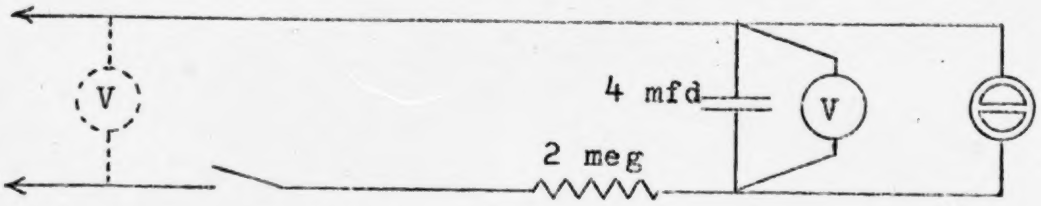
GATHERING THE DATA:

Precaution: Do not touch circuit while power supply is on. Turn off when making or changing connections.

1. Test neon bulb across 110v AC
2. a) Wire circuit as shown with power supply adjusted for minimum voltage.



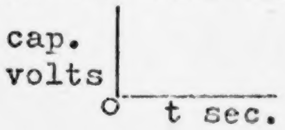
   b) Close switch, slowly increase voltage, and note the voltage when neon bulb first brightens. (do not exceed 100v)--repeat several times to insure consistency.
   c) Adjust voltage to brighten bulb, then slowly decrease voltage, and observe voltage at which bulb goes out--repeat several times to insure consistency.
3. a) Wire the following circuit:



   b) Adjust power supply to 100v.
   c) Close switch and time for T (10 flashes).
   -count first flash zero as timing starts.
   -check several times for consistency--use mean if necessary.
   -record values in table.

R	C	T (sec)	Period
2 meg	4 mfd		

4. Repeat step #3 for:
   a) 1 meg & 4 mfd
   b) 2 meg & 0.5 mfd
   c) 1 meg & 0.5 mfd
   d) 2 meg & 1 mfd
   e) 1 meg & 1 mfd
   f) 1 meg & 0.1 mfd
5. Using universal time constant chart, graph 3 complete oscillations starting from switch closing for the 2 meg--4 mfd combination.



6. Using universal chart, the data of step #2 and the available capacitors and resistors, design, construct and check an 8 vibrations/min relaxation oscillator.

SUMMATION:

1. Explain how relaxation oscillator helps produce TV picture.
2. Why are starting & stopping voltages of neon bulb different?

Station 215 Exp. # 85 Team

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "It is almost impossible for a student to make a beginning in any branch of theoretical physics without some understanding of vector analysis. ...to completely specify a vector quantity one must give both its magnitude and its direction. This necessity...is especially evident when one is concerned with the relationship of two or more vectors. Thus if a man travels a stretch of 10 miles and then a stretch of 5 miles more, he is by no means necessarily 15 miles from home."
>
> William S. Franklin

PROBLEM: To investigate AC voltage distributions in series circuits containing resistors and capacitors.

APPARATUS:

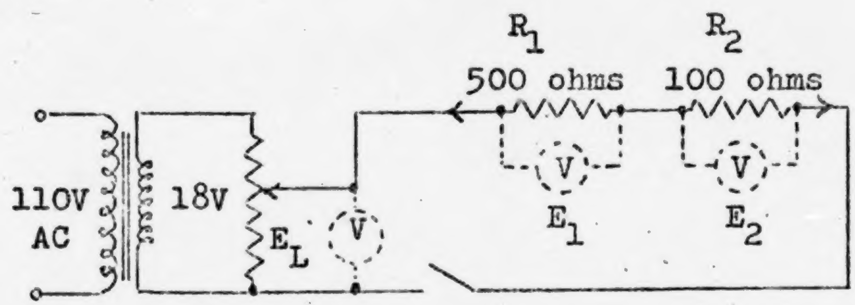
VTVM	4 mfd capacitor
Potentiometer	2 1mfd "
5K rheostat	500 ohm resistance
Peg board	100 ohm "
SPST switch	12 clip leads
Transformer	

REFERENCES:

1. Philco, Fund. of AC, Vol. II, pp. 44-47

GATHERING THE DATA:

1. a) Wire circuit as shown:

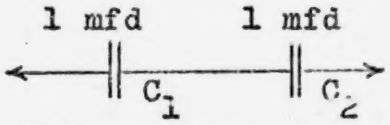


VTVM must warm up before use

b) Adjust line voltage for $E_L = 6v$ and measure and record E_1 and E_2

c) Place rheostat in series with R_1 and R_2, concurrently adjust $E_L = 7v$ and E (rheostat) = 1v.
--measure and record E_1 and E_2.

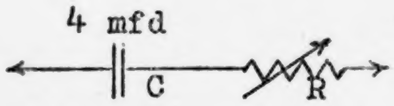
2. a) Wire circuit as shown:



b) Adjust line voltage for $E_L = 6v$ and measure and record E_1 and E_2.

c) Place $C_3 = 4$ mfd in series with C_1 and C_2, adjust line voltage $E_L = 9v.$, and measure and record E_1, E_2, and E_3.

3. a) Wire circuit as shown:



b) Concurrently adjust E_L and E_R to the prescribed values shown in table, measure E_C, and complete table.

Circuit	E_L	E_R	E_C	$E_R + E_C$
I	6.5v	1.6v		
II	3.7v	1.2v		
III	2.5v	0.7v		
IV	4.1v	0.9v		
V	5.3v	2.8v		

SUMMATION:

1. Within the limitations of meter and component accuracy, does experimental

> evident when one is concerned with the relationship of two or more vectors. Thus if a man travels a stretch of 10 miles and then a stretch of 5 miles more, he is by no means necessarily 15 miles from home."
>
> William S. Franklin

PROBLEM: To investigate AC voltage distributions in series circuits containing resistors and capacitors.

APPARATUS:

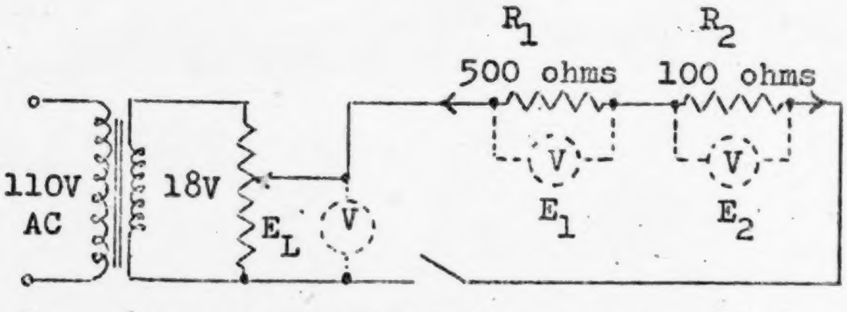
- VTVM
- Potentiometer
- 5K rheostat
- Peg board
- SPST switch
- Transformer
- 4 mfd capacitor
- 2 1mfd "
- 500 ohm resistance
- 100 ohm "
- 12 clip leads

REFERENCES:

1. Philco, Fund. of AC, Vol. II, pp. 44-47

GATHERING THE DATA:

1. a) Wire circuit as shown:

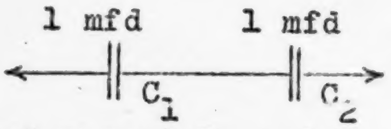


VTVM must warm up before use

b) Adjust line voltage for E_L = 6v and measure and record E_1 and E_2

c) Place rheostat in series with R_1 and R_2, concurrently adjust E_L = 7v and E (rheostat) = 1v.
--measure and record E_1 and E_2.

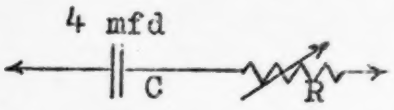
2. a) Wire circuit as shown:



b) Adjust line voltage for E_L = 6v and measure and record E_1 and E_2.

c) Place C_3 = 4 mfd in series with C_1 and C_2, adjust line voltage E_L = 9v., and measure and record E_1, E_2, and E_3.

3. a) Wire circuit as shown:



b) Concurrently adjust E_L and E_R to the prescribed values shown in table, measure E_C, and complete table.

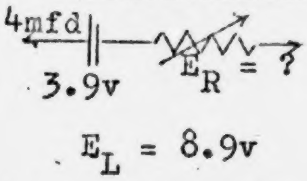
Circuit	E_L	E_R	E_C	$E_R + E_C$
I	6.5v	1.6v		
II	3.7v	1.2v		
III	2.5v	0.7v		
IV	4.1v	0.9v		
V	5.3v	2.8v		

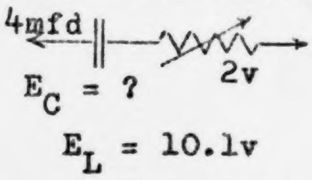
SUMMATION:

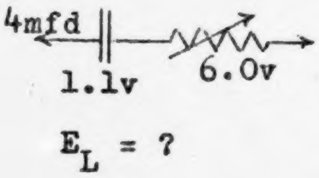
1. Within the limitations of meter and component accuracy, does experimental data of steps #1 and #2 conform to Kirchhoff's voltage law? Explain.

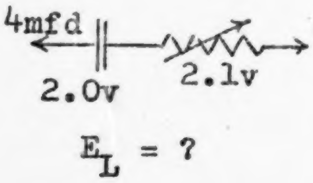
2. Does Kirchhoff's voltage law apply to the experimental data of step #3? If not, apply vector methods and analysis.

3. Using vectors, determine the missing voltages, and then check findings with measurements in actual circuits.









4. According to experimental data:
   a) How is Kirchhoff's voltage law affected when both capacitors and resistors appear in the same AC circuit?
   b) In what respect does it still hold?
   c) What is the angle between the capacitor voltage vector and the resistance voltage vector?

Station

AVIATION HIGH SCHOOL

Exp.# 86

APPLIED PHYSICS LABORATORY

Team

> "To the average person it probably seems self-evident that we know more about a chair than an electron. The reverse is obviously true to a physicist since there would not even be universal agreement about what constituted the definition of a chair, whereas an electron is a precisely defined entity upon which physicists all over the world are in complete accord."
>
> Gaylord P. Harnwell

PROBLEM: To develop and to test the equation for capacitive reactance:

$$X_c = \frac{1}{2\pi fC}$$

APPARATUS:

0-10ma AC meter	VTVM
Signal generator	Fuse & holder
2 1mfd capacitors	20 clip leads
Graph paper & board	SPST switch

REFERENCES:

1. Timbie, Basic Elec. for Communications, pp. 316-8
2. Turner, Basic Electricity, pp. 116-8

THEORY:

a) If t is the time for complete charge or discharge of a capacitor connected to $\overline{AC}$, then: $t = 1/4$ the time for one cycle $= 1 \div 4f$

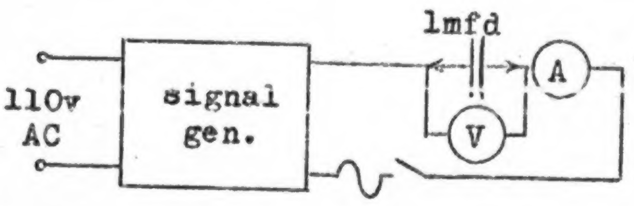
b) Max. charge flowing into capacitor: $Q \text{ (coulombs)} = I_{av} \text{ (amps)} \times t \text{ (sec)}$
$= I_{av} \times \frac{1}{4f}$

c) Since $Q_{max} = V_{max} \times C \therefore V_{max}C = \frac{I_{av}}{4f} \longrightarrow V_{max} = \frac{I_{av}}{4fC}$

d) But $I_{av} = 0.637 I_{max} \therefore V_{max} = \frac{0.637 I_{max}}{4fC} = \frac{I_{max}}{2\pi fC}$ (or gen. $V = \frac{I}{2\pi fC}$)

e) and since $V = X_c I \therefore X_c = \frac{V}{I} \rightarrow X_c = \frac{1}{2\pi fC}$

GATHERING THE DATA:

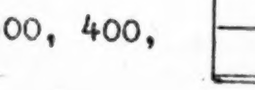


Caution: DO NOT press red button if meter reading exceeds 1 div.

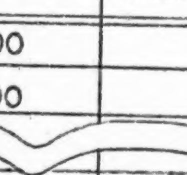
1. a) Wire circuit.
   b) Set signal generator for 200 cycle sine wave with zero amplitude.
   c) Close switch, adjust signal generator for 10ma (approx.) & record corresponding voltage in table.
2. Repeat step #1 for 300, 400, 500, ... 2000 cycles.
3. Compute X_c using:
   a) meter readings
   b) frequency and capacity

Cycles	V Volts	I Amps	$X_c = V/I$ ohms	$X_c = \frac{1}{2\pi fC}$
200				
300				
2000				

4. Repeat above for: a)



b)



(each capacitor 1mfd--use 200, 400, 800, and 1600 cycles only)

5. Graphically verify: $I_{av} = .637 I_{max}$
   a) generate sine wave.
   b) det. area of 1/2 sine wave by counting graph paper squares

electron is a precisely defined entity upon which physicists all over the world are in complete accord."

Gaylord P. Harnwell

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Signal generator	Fuse & holder
2 1mfd capacitors	20 clip leads
Graph paper & board	SPST switch

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b) Max. charge flowing into capacitor: $Q \text{ (coulombs)} = I_{av} \text{ (amps)} \times t \text{ (sec)}$

$$= I_{av} \times \frac{1}{4f}$$

c) Since $Q_{max} = V_{max} \times C \therefore V_{max} C = \frac{I_{av}}{4f} \longrightarrow V_{max} = \frac{I_{av}}{4fC}$

d) But $I_{av} = 0.637 I_{max} \therefore V_{max} = \frac{0.637 I_{max}}{4fC} = \frac{I_{max}}{2\pi fC}$ (or gen. $V = \frac{I}{2\pi fC}$)

e) and since $V = X_c I \therefore X_c = \frac{V}{I} \rightarrow X_c = \frac{1}{2\pi fC}$

GATHERING THE DATA:

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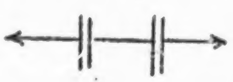
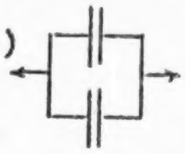
4. Repeat above for: a)

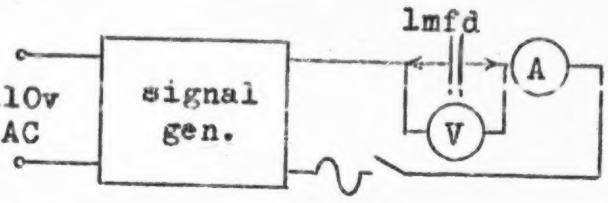


b)



(each capacitor 1mfd--use 200, 400, 800, and 1600 cycles only)

5. Graphically verify: $I_{av} = .637 I_{max}$
   a) generate sine wave.
   b) det. area of 1/2 sine wave by counting graph paper squares.
   c) divide area by base to get average height (I_{av}).
   (or cut out sine wave & use its mass to determine I_{av})



Caution:
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Cycles	V Volts	I Amps	$X_c = V/I$ ohms	$X_c = \frac{1}{2\pi fC}$
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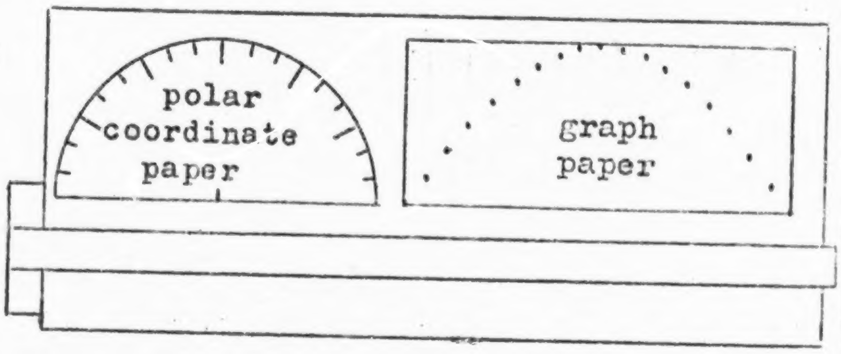
300				
2000				



SUMMATION:

1. According to experimental data:
   a) have theoretical calculations been confirmed? Explain.
   b) how does capacitive reactance vary with frequency?
   c) how is total capacity in parallel computed? In series?
2. Try verifying $I_{av} = 0.637 I_{max}$ using the average of sine table values. Show calculations.
3. Define capacity and capacitive reactance, and explain how capacitive reactance opposes electron flow.

Station

Exp.# 87

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

Team

> "This constitutes Newton's greatness. He was certainly no planetary theorist in the traditional sense; he was not a 'coordinate-fixer' or an 'orbit-shaper' as had been Ptolemy, Copernicus and Kepler. He was not, like Stevin, Toricelli or Viviani, an 'experimentalist'. He was primarily a systematizer; an architect, not a bricklayer."
>
> Norwood Russell Hanson

PROBLEM: To measure and analyze the non-resistive opposition of coils to alternating current.

APPARATUS:

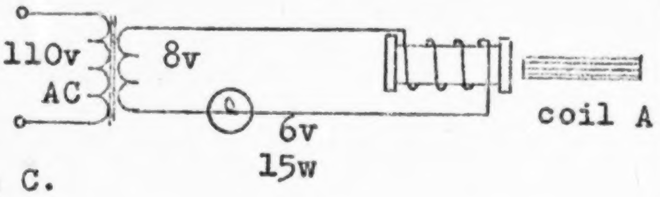
Audio Signal Generator	VTVM
10ma AC meter	SPST switch
Ohmmeter	Coils
Laminated Iron core	Leads
6v lamp and base	

REFERENCES:

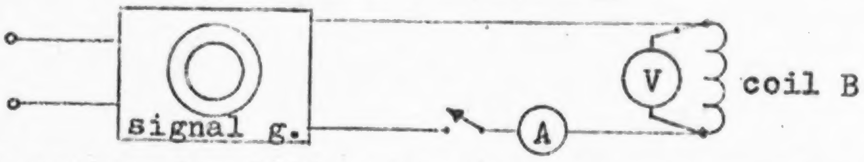
1. Van Valkenburgh, Basic Electricity, pp. 3-61 & 70
2. Philco, Fund. of AC & Circuit Analysis pp. 50-2
3. White, Modern College Physics, pp. 466-8

GATHERING THE DATA:

1. a) Wire circuit as shown.
   b) Slide laminated iron core into coil and observe effect on bulb.



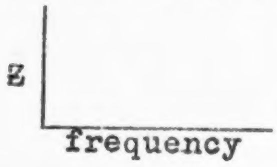
2. Measure & record resistances of coils A,B,& C.
3. Wire circuit:



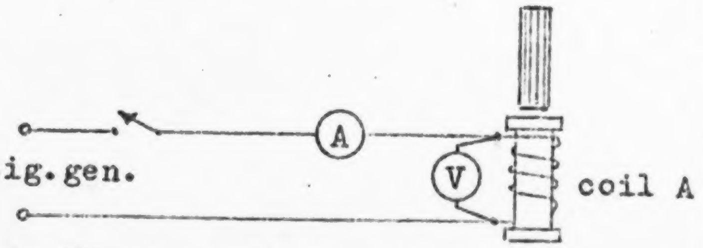
   a) Set signal generator for 2000 cycles/sec. & zero amplitude. (if signal generator has attenuator switch, set for min. output amplitude)
   b) Switch signal generator on, wait for it to warm up & close circuit switch.
   c) Adjust amplitude for large ammeter reading--preferably, but not exceeding, 10ma.--measure voltage across coil and record reading in table.
   d) Reduce amplitude to zero, set frequency to 1800 cycles/sec., adjust amplitude for the same ammeter reading as in step c, and measure and record coil voltage.
   e) Repeat d for frequencies decreasing in 200 cycles/sec. steps.

coil	cycles/sec	A	V	Z = V/A
B	2000			
B	1800			
B	200			

f) Plot:



4. Repeat step #3 for coil C.
5. a) Wire circuit as shown:
   b) Set for 2000 cycles/sec. frequency, adjust amplitude for 10ma current in coil, & measure voltage across coil.
   c) Repeat b with laminated core inserted in ½" steps into coil.



coil	cycles/sec	core depth	A	V	Z
A	2000	1/2"			

d) Plot:

a systematizer, an architect, not a bricklayer."

Norwood Russell Hanson

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APPARATUS:

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10ma AC meter
Ohmmeter
Laminated Iron core
6v lamp and base
VTVM
SPST switch
Coils
Leads

REFERENCES:

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2. Philco, Fund. of AC & Circuit Analysis pp. 50-2
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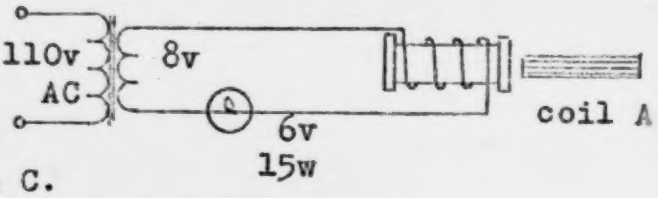
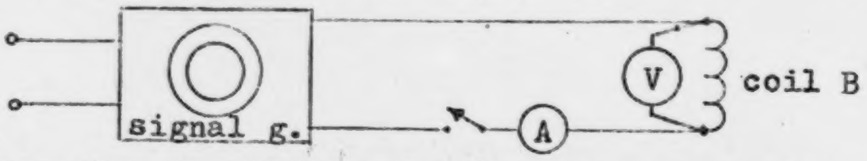
GATHERING THE DATA:



1. a) Wire circuit as shown.
   b) Slide laminated iron core into coil and observe effect on bulb.

2. Measure & record resistances of coils A,B,& C.

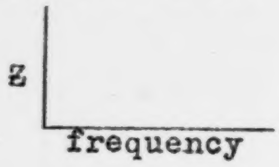
3. Wire circuit:



   a) Set signal generator for 2000 cycles/sec & zero amplitude. (if signal generator has attenuator switch, set for min. output amplitude)
   b) Switch signal generator on, wait for it to warm up & close circuit switch.
   c) Adjust amplitude for large ammeter reading--preferably, but not exceeding, 10ma.--measure voltage across coil and record reading in table.
   d) Reduce amplitude to zero, set frequency to 1800 cycles/sec., adjust amplitude for the same ammeter reading as in step c, and measure and record coil voltage.
   e) Repeat d for frequencies decreasing in 200 cycles/sec. steps.

coil	cycles/sec	A	V	Z = V/A
B	2000			
B	1800			
B	200			

   f) Plot:



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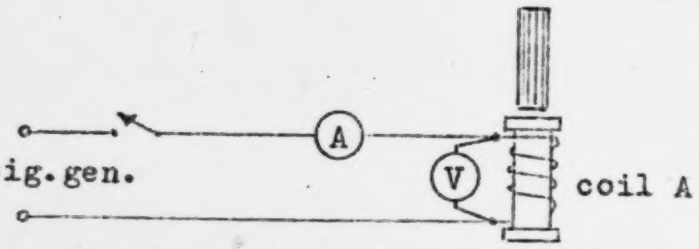
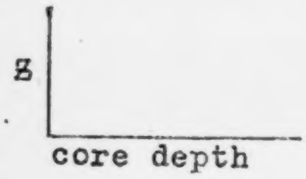
   c) Repeat b with laminated core inserted in ½" steps into coil.



coil	cycles/sec	core depth	A	V	Z
A	2000	1/2"			
A	2000	1"			

   d) Plot:



SUMMATION:

1. According to experimental data for air core coils, how does opposition to electron flow vary with frequency.

2. At higher frequencies, coil resistance plays an increasingly minor role in coil impedance. Explain.

3. Using graph data, $X_L = 2\pi fL$, and $X_L \doteq Z$, calculate inductance L (in henries) for coils B and C.

4. a) Devise and implement a test for determining the maximum and minimum inductance of coil C.
   b) Explain the effect the iron core has on the coil's inductance and the coil's inductive reactance.

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Station

AVIATION HIGH SCHOOL

Exp.# 88

APPLIED PHYSICS LABORATORY

Team

> "In considering the subject of electrical measurements a variety of viewpoints is possible. At one extreme, measurements constitute a system of philosophy is which cause and effect can be kept in an orderly array. (This viewpoint is more easily maintained at the desk than in the laboratory). At the other extreme, measurement, may be considered a contest in which the adversary is what has been called 'the law of the natural cussedness of inanimate objects'."
>
> Forest K. Harris

PROBLEM: To experimentally examine series circuit resonance and to plot a resonance curve for a circuit.

APPARATUS:

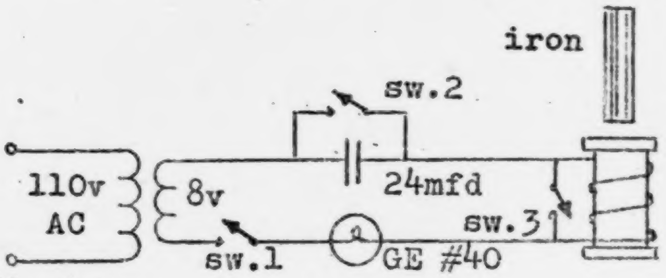
Audio signal generator
AC ma meter
Transformer
3 SPST switches
GE #40 bulb & base
VTVM
Choke
Leads
Iron core
Capacitors

REFERENCES:

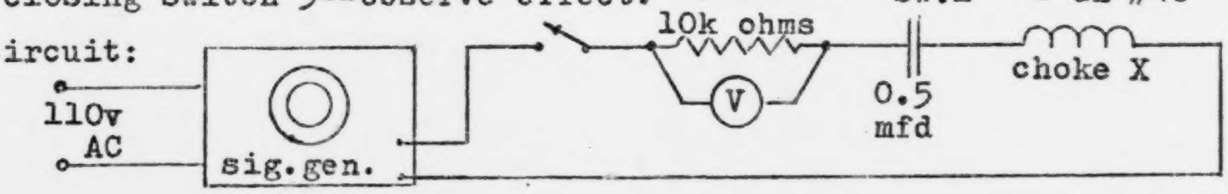
1. Philco, Fund. of AC and Circuit Analysis, pp. 110-14
pp. 123-4
2. VanValkenburgh, Basic Electricity, pp. 4-33
pp. 4-35
3. Timbie, Basic Electricity for Communications, pp. 333-8

GATHERING THE DATA:

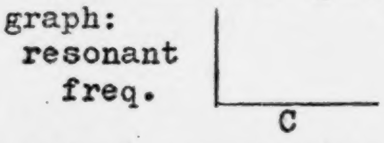
1. Wire circuit:
   a) Close sw.1 & adjust iron core until lamp is brightest.
   b) Short out capacitor(s) by closing switch 2--observe effect on lamp.
   c) Open switch 2 & then short out coil by closing switch 3--observe effect.

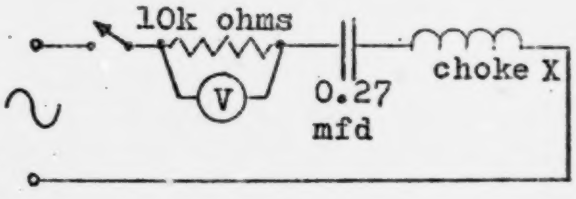


2. Wire circuit:



   a) Experimentally determine circuit's resonant frequency by adjusting signal generator's frequency and amplitude for peak voltage (4v) across 10k ohm resistor.
   b) Repeat for 0.25, 0.2, 0.1, 0.05, 0.01, 0.005, and 0.0025 mfd. capacitors. (use the same peak voltage for each)
   c) Plot graph:

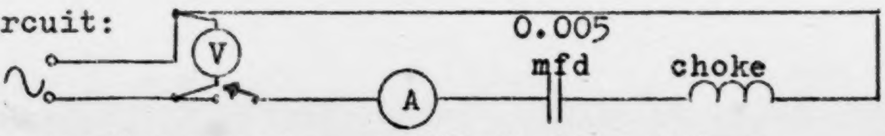




3. Determine inductance of choke X.
   a) Adjust input frequency for resonance.
   b) Ignoring choke resistance:

$$X_L = X_C \longrightarrow 2\pi fL = \frac{1}{2\pi fC} \longrightarrow L = \frac{1}{4\pi^2 f^2 C}$$

4. Wire circuit:



   a) Set signal generator amplitude for minimum.

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Leads
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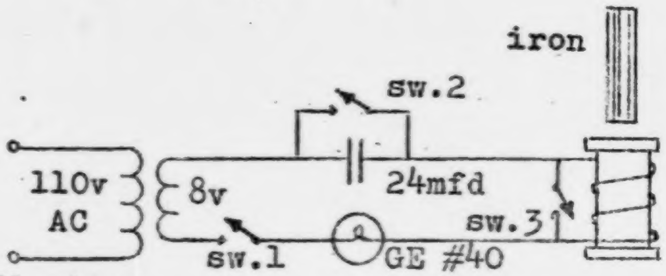
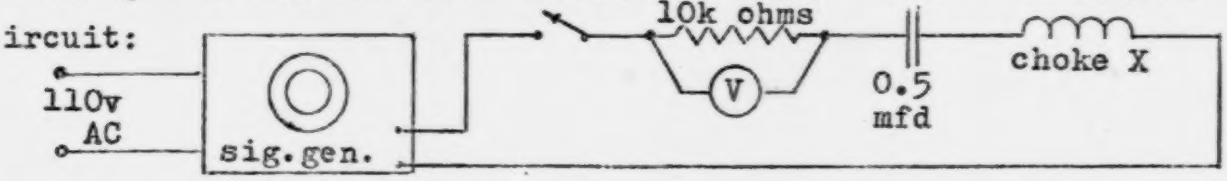


2. Wire circuit:



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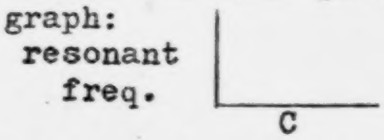

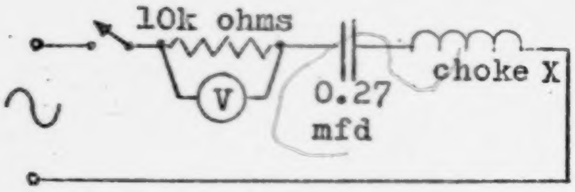

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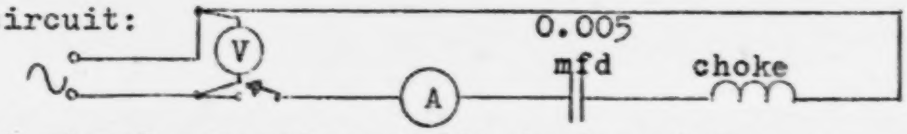
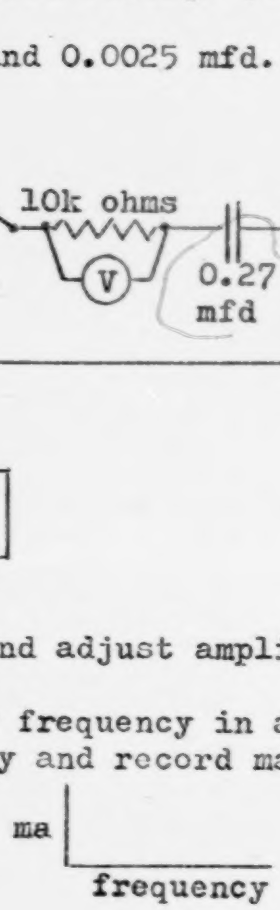


   a) Set signal generator amplitude for minimum.
   b) Close switch, adjust frequency for resonance, and adjust amplitude for maximum reading on milliammeter.
   c) Keeping signal generator voltage constant, vary frequency in approx. 20 cycle steps above and below resonant frequency and record ma readings.

Frequency	Volts	ma

   d) Plot:



SUMMATION:

1. Explain observations of step #1.
2. Does data of step #2 agree with: $f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{L}} \cdot \frac{1}{\sqrt{C}} \rightarrow f \propto \frac{1}{\sqrt{C}}$
3. a) Explain signigicance of resonance curve.
   b) How will increased resistance in a series resonant circuit affect its resonance curve.
   c) Devise & implement an experiment for testing conclusions regarding resistance and a resonance curve.

Station ⬡ Exp.# 89 Team ○

AVIATION HIGH SCHOOL APPLIED PHYSICS LABORATORY

> "Do not teach physics to minds not yet ready to assimilate it. Mme de Sévigné used to say, speaking of young children: 'Before you feed them the food of a truck driver, find out if they have the stomach of a truckdriver.' "
>
> Pierre Duhem

> "Shall I refuse my dinner because I do not fully understand the process of digestion."
>
> Oliver Heaviside

PROBLEM: To experimentally examine parallel circuits in resonance, and to observe and explain the damped harmonic oscillations of a resonant tank circuit.

APPARATUS:

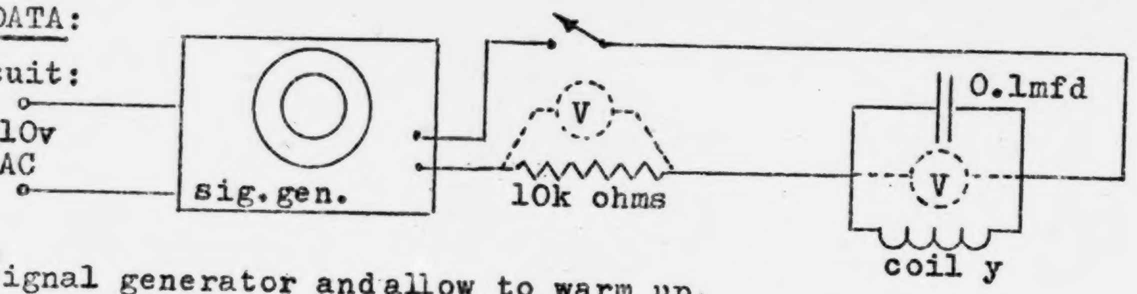
Oscilloscope
Inductors
Capacitors
Potentiometer
Signal generator
VTVM
DPDT switch
Clip leads
10k resistor

REFERENCES:

1. Timbie, Basic Electricity for Communications, pp. 361-4
2. Van Valkenburgh, Basic Electricity, pp. 4-58, 4-62
3. Philco, Fund. of AC and AC Circuit Analysis, pp. 125-35

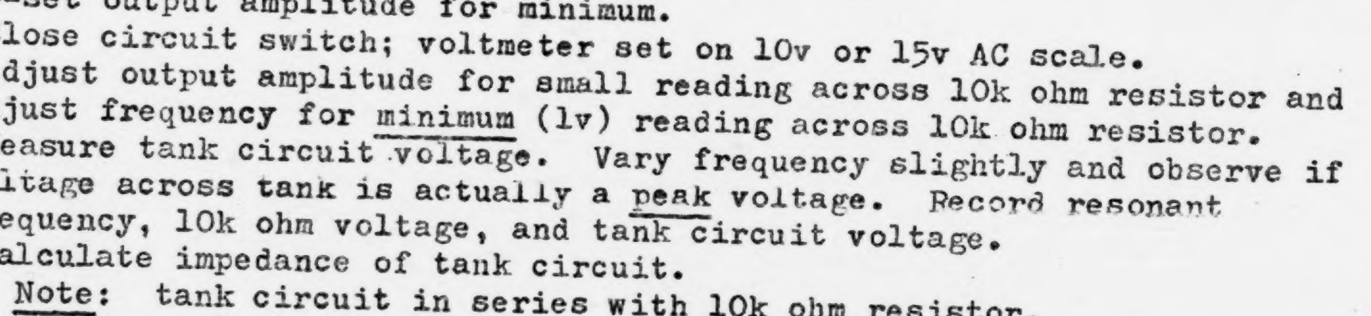
GATHERING THE DATA:

1. a) Wire circuit:

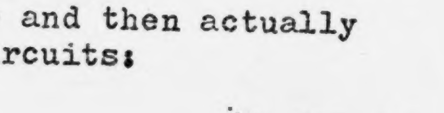


b) Turn on signal generator and allow to warm up.
--set output amplitude for minimum.
c) Close circuit switch; voltmeter set on 10v or 15v AC scale.
d) Adjust output amplitude for small reading across 10k ohm resistor and adjust frequency for minimum (1v) reading across 10k ohm resistor.
e) Measure tank circuit voltage. Vary frequency slightly and observe if voltage across tank is actually a peak voltage. Record resonant frequency, 10k ohm voltage, and tank circuit voltage.
f) Calculate impedance of tank circuit.
Note: tank circuit in series with 10k ohm resistor.
g) Assuming $X_L \doteq X_C$ for resonant condition, determine coil y's inductance.

2. Using the calculated inductance of step #1, calculate and then actually measure the resonant frequencies of the following circuits:



3. a) Determine the inductance of coil W using:
b) Repeat a using 0.005mfd capacitor.



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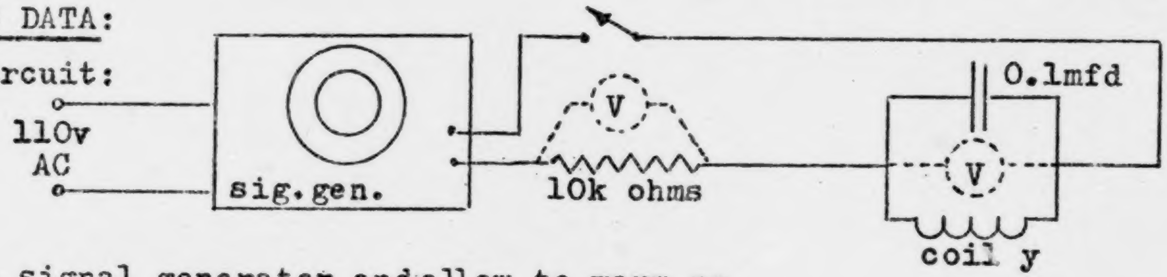

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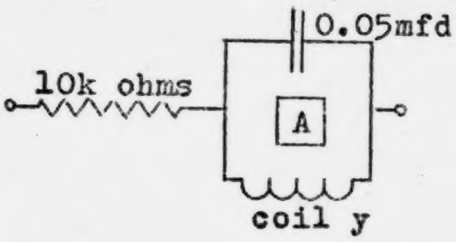
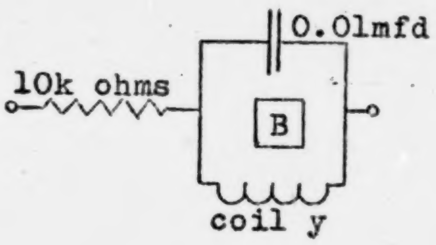
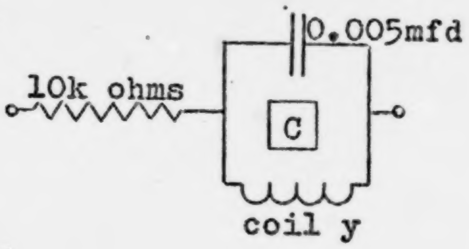
--set output amplitude for minimum.
c) Close circuit switch; voltmeter set on 10v or 15v AC scale.
d) Adjust output amplitude for small reading across 10k ohm resistor and adjust frequency for minimum (1v) reading across 10k ohm resistor.
e) Measure tank circuit voltage. Vary frequency slightly and observe if voltage across tank is actually a peak voltage. Record resonant frequency, 10k ohm voltage, and tank circuit voltage.
f) Calculate impedance of tank circuit.
Note: tank circuit in series with 10k ohm resistor.
g) Assuming $X_L \doteq X_C$ for resonant condition, determine coil y's inductance.

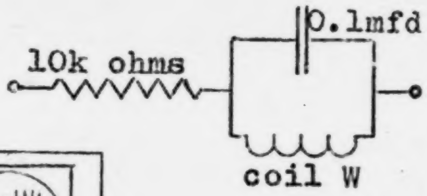
2. Using the calculated inductance of step #1, calculate and then actually measure the resonant frequencies of the following circuits:



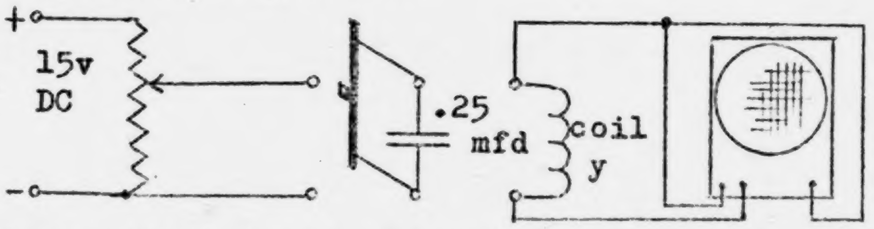




3. a) Determine the inductance of coil W using:
b) Repeat a using 0.005mfd capacitor.



4. a) Wire circuit:



b) Connect coil to vertical input and upper end of coil to external sync.
c) Set sweep frequency for 15.
d) Charge capacitor by connecting it to the potentiometer.
e) Flick switch to coil & adjust scope for a stable picture of discharge through coil.
f) Increase charging voltage in convenient increments--observe wave pattern.

SUMMATION:

1. Why does min. voltage across resistor imply resonance?
Why does peak voltage across tank circuit imply resonance?
2. Design a tank circuit which will afford maximum resistance to a 60 cycle/sec. frequency. (TEST)

Station AVIATION HIGH SCHOOL Exp.# 90 APPLIED PHYSICS LABORATORY Team

> "Eddington has said that whereas in the nineteenth century the creator was regarded as an engineer, in the twentieth century he is a pure mathematician."
>
> C. G. Darwin
>
> "A little learning is a dang'rous thing;
> Drink deep or taste not the Pierian Spring."
>
> Alexander Pope

PROBLEM: To measure frequencies with an oscilloscope.

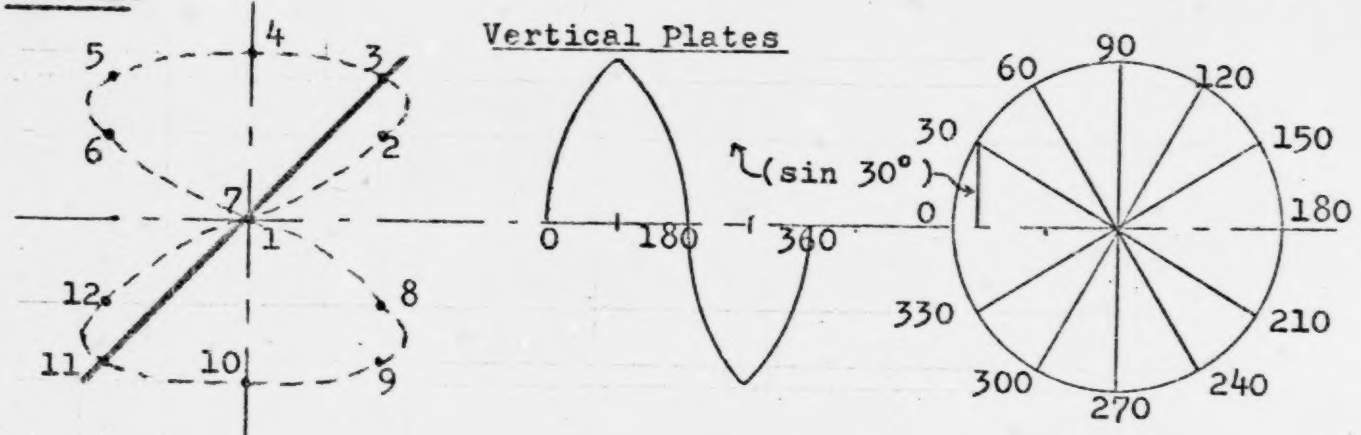
APPARATUS:

Oscilloscope
Audio signal generator
Lissajous sketching paper

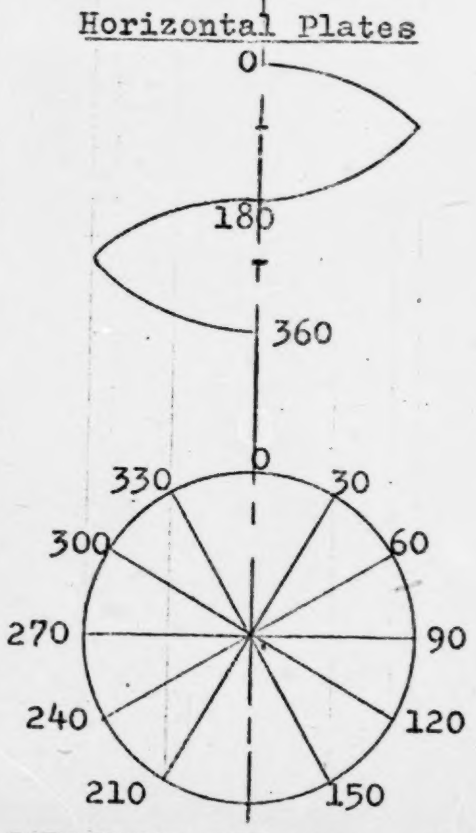
REFERENCES:

1. DeFrance, Electron Tubes & Semiconductors, pp. 145-56
2. Sears & Zemansky, University Physics, pp. 268-271
3. Turner, Basic Electronic Test Procedures, pp. 124-126

THEORY:



4
5
3
6
2
7
1
12
8
11
10
9
Vertical Plates
0
180
360
(sin 30°)
90
60
120
30
150
0
180
330
210
300
240
270



Horizontal Plates
0
180
360
0
330
30
300
60
270
90
240
120
210
150

I. Line —— Vert. & Horiz. Voltages Equal & in Phase

-figure secured via intersection of the corresponding sine values:

Vertical Plate		Horizontal Plate
sin 0	&	sin 0
sin 30	&	sin 30
sin 60	&	sin 60
etc.		etc.

II. Line – – – Horiz. Freq. 2x Vert. Freq. & in Phase at 0

-figure secured via intersection of:

Vertical Plate		Horizontal Plate
sin 0	&	sin 0
sin 30	&	sin 60
sin 60	&	sin 120 etc.

(Numbers on scope figure indicate order in which figure was developed.) NOTE: Lissajous figures can be developed directly from the circles without developing the sine waves which have been introduced only for clarity.

GATHERING THE DATA: Identify frequencies using Lissajous figures

"A little learning is a dang'rous thing;
Drink deep or taste not the Pierian Spring."
Alexander Pope

PROBLEM: To measure frequencies with an oscilloscope.

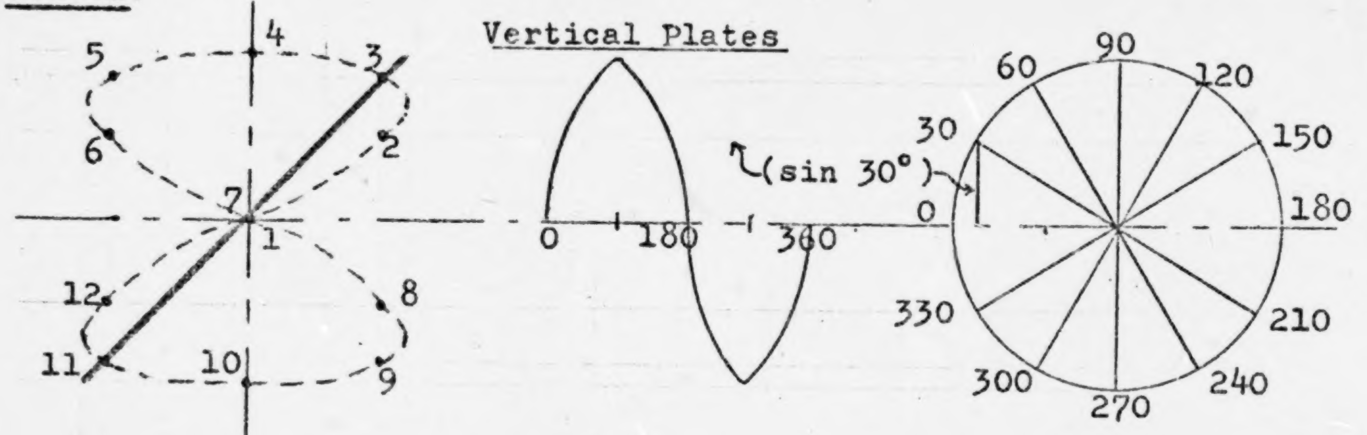
APPARATUS:

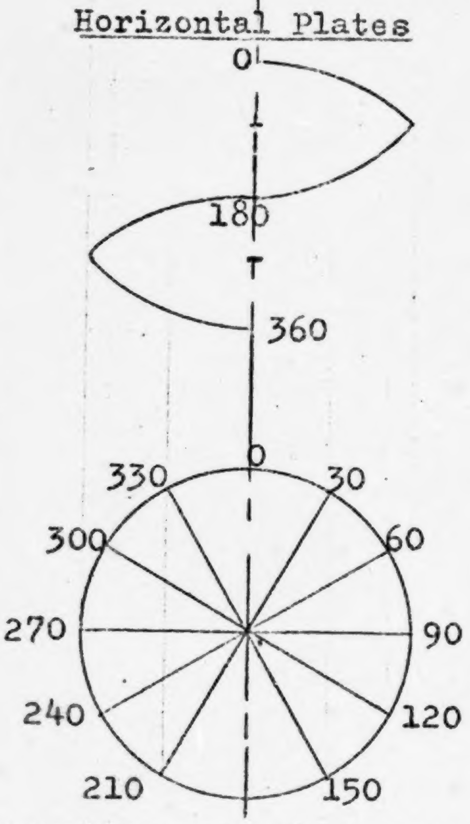
Oscilloscope
Audio signal generator
Lissajous sketching paper

REFERENCES:

1. DeFrance, Electron Tubes & Semiconductors, pp. 145-56
2. Sears & Zemansky, University Physics, pp. 268-271
3. Turner, Basic Electronic Test Procedures, pp. 124-126

THEORY:





I. Line ——— Vert. & Horiz. Voltages Equal & in Phase

-figure secured via intersection of the corresponding sine values:

Vertical Plate		Horizontal Plate
sin 0	&	sin 0
sin 30	&	sin 30
sin 60	&	sin 60
etc.		etc.

II. Line - - - Horiz. Freq. 2x Vert. Freq. & in Phase at 0

-figure secured via intersection of:

Vertical Plate		Horizontal Plate
sin 0	&	sin 0
sin 30	&	sin 60
sin 60	&	sin 120 etc.

(Numbers on scope figure indicate order in which figure was developed.) NOTE: Lissajous figures can be developed directly from the circles without developing the sine waves which have been introduced only for clarity.

GATHERING THE DATA: Identify frequencies using Lissajous figures.

1. Connect 1v.PP to vertical input with sweep circuit off & attenuation set for minimum, and adjust vertical amplitude for a 2" centered deflection line.
2. Disconnect the vertical input, connect the signal generator with amplitude output set mid-scale to horizontal input, and adjust for 2" centered deflection line.
3. Reconnect vertical input as/step 1, set generator frequency approx. equal to 60 cycles/sec, & then finely adjust frequency until a stationary circle appears on the scope. Copy the figure.
4. Set signal generator frequency approx. equal to 120 cycles/sec & then finely adjust frequency until a stationary figure symmetric about the x axis and symmetric about the y axis appears on the scope. Copy the figure.
5. Repeat step 4 for 180, 240, 360, 480, 560, 30, 20, 40, 60, 80 & 90 cycles/sec.

SUMMATION:

1. a) Using Lissajous sketching paper, theoretically develop the Lissajous figures for several of the frequencies tested. (Shift phase for clarity.)
   b) Generalize the theoretical and experimental findings.

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> "The inventor's very lack of technical knowledge is often the secret of his success.... There was a celebrated inventor whose employees hung upon the walls of his laboratory a placard, of which he was very proud, that read: 'The poor fool didn't know enough to know that it couldn't be done, so he went ahead and did it.' "
>
> W. F. G. Swann

PROBLEM: To apply semiconductors in half and full wave rectifiers and to square wave generation.

APPARATUS:

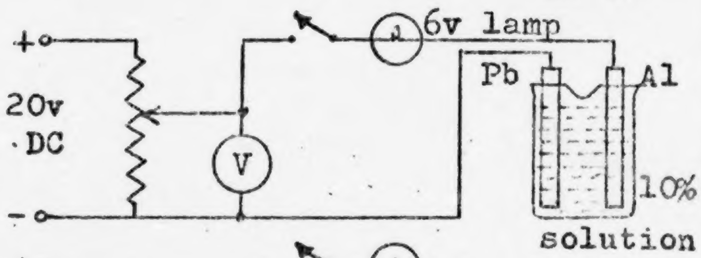
Oscilloscope VTVM 6v lamp
Milliammeter Rheostat SPST switch
2 5100 ohm resistors #6 & 2D bat.
1B3 tube and base Semi-conduc.
Beaker & Pb & Al strips Clip leads
10% ammonium phosphate solution
1/8a fuse

REFERENCES:

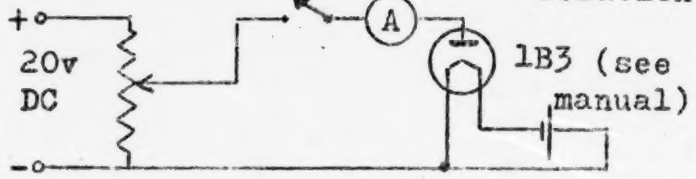
1. Turner, Semi-conductor Devices, pp. 1-12
   Basic Electricity, pp. 228-32
2. Philco, Tubes & Semiconductors, pp. 13-14, 41-44
3. VanValkenburgh, Basic Electronics, pp. 1: 23-9; 6: 10-12, 16-17

GATHERING THE DATA:

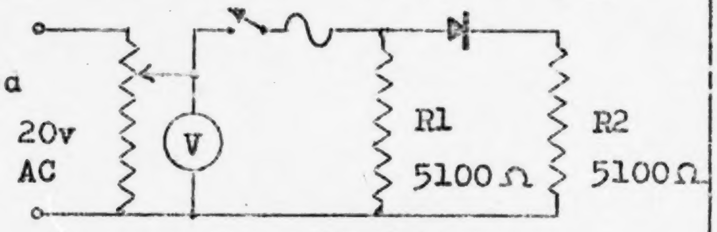
1. a) Wire circuit.
   b) Set applied voltage at minimum before closing switch.
   c) Adjust for 6v, close switch and observe lamp.
   d) Reverse polarity & observe lamp.



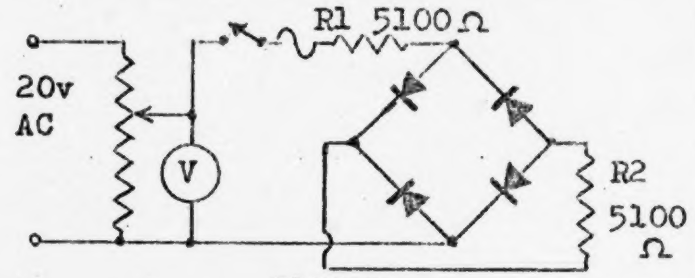
2. a) Wire circuit.
   b) Gradually increase plate voltage and observe effect on plate current.
   c) Reverse leads and repeat b.



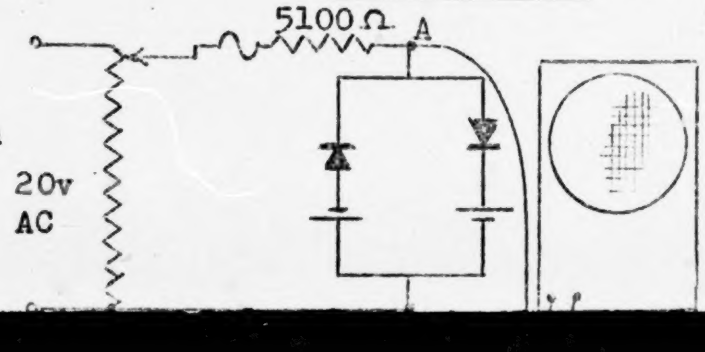
3. a) Wire circuit.
   b) Adjust voltage for 10v AC.
   c) Close switch and adjust scope connected across R1 for an integral number of repeated wave forms.
   d) Check wave forms across R2.
   e) Reverse diode and repeat d.



4. a) Wire circuit.
   b) Adjust voltage for 10v AC.
   c) Close switch & adjust scope connected across R1 for an integral number of repeated wave forms.
   d) Check wave forms across R2.



5. a) Wire circuit.
   b) Apply 20v AC.
   c) Check wave form across pts. A and B.
   d) Decrease voltage and observe effect on wave form across pts. A and B.



done; so he went ahead and did it." W. F. G. Swann

PROBLEM: To apply semiconductors in half and full wave rectifiers and to square wave generation.

APPARATUS:

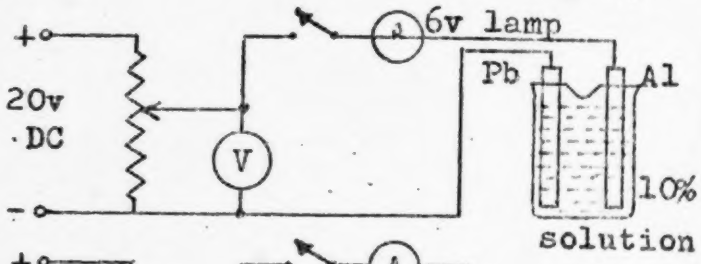
Oscilloscope
Milliammeter
2 5100 ohm resistors
1B3 tube and base
Beaker & Pb & Al strips
10% ammonium phosphate solution
1/8a fuse
VTVM
Rheostat
6v lamp
SPST switch
#6 & 2D bat.
Semi-conduc.
Clip leads

REFERENCES:

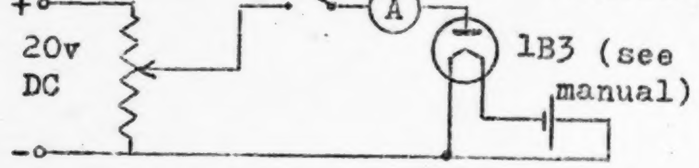
1. Turner, Semi-conductor Devices, pp. 1-12
   Basic Electricity, pp. 228-32
2. Philco, Tubes & Semiconductors, pp. 13-14
   41-44
3. VanValkenburgh, Basic Electronics, pp. 1: 23-9
   6: 10-12
   16-17

GATHERING THE DATA:

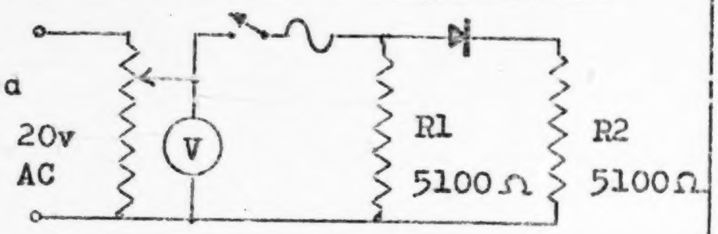
1. a) Wire circuit.
   b) Set applied voltage at minimum before closing switch.
   c) Adjust for 6v, close switch and observe lamp.
   d) Reverse polarity & observe lamp.



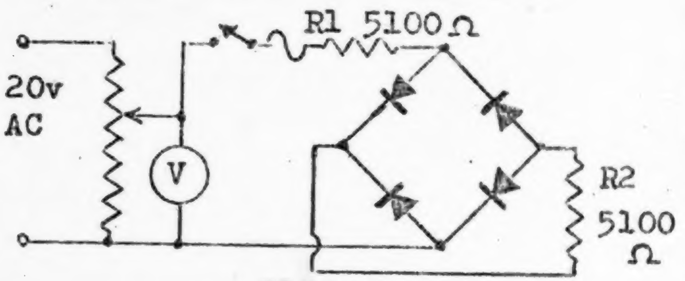
2. a) Wire circuit.
   b) Gradually increase plate voltage and observe effect on plate current.
   c) Reverse leads and repeat b.



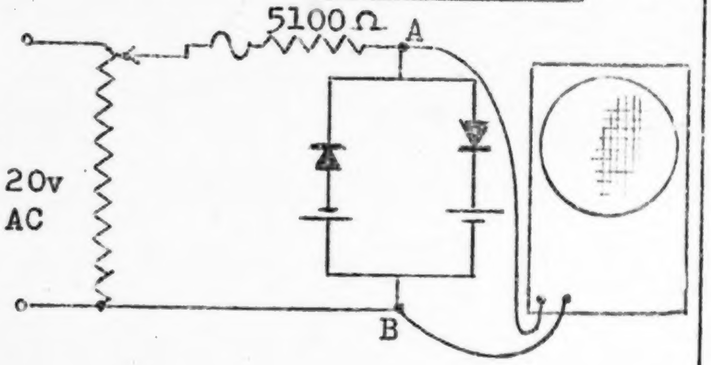
3. a) Wire circuit.
   b) Adjust voltage for 10v AC.
   c) Close switch and adjust scope connected across R1 for an integral number of repeated wave forms.
   d) Check wave forms across R2.
   e) Reverse diode and repeat d.



4. a) Wire circuit.
   b) Adjust voltage for 10v AC.
   c) Close switch & adjust scope connected across R1 for an integral number of repeated wave forms.
   d) Check wave forms across R2.



5. a) Wire circuit.
   b) Apply 20v AC.
   c) Check wave form across pts. A and B.
   d) Decrease voltage and observe effect on wave form across pts. A and B.



SUMMATION:

1. According to experimental findings, what kind of device is the ammonium phosphate solution with the lead and aluminum strips? Relate operation to polarity.
2. Describe the operation of 1B3 tube--with positive plate--with negative plate.
3. Trace electron flow for both halves of the AC cycle in step #3.
4. Trace electron flow for both halves of the AC cycle in step #4.
5. a) Describe the output wave of circuit #5. Explain.
   b) Describe the functions of diodes, biasing batteries, & the 5100 ohm resistor.
   c) Explain the effect on the output wave of reduced applied voltage.